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# PROCEEDINGS

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PROCEEDINGS

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April 1894.

## XIV. *On the Design and Winding of Alternate-Current Electromagnets.* *By* Silvanus P. Thompson, *D.Sc., F.R.S., and* Miles Walker*.

1. In designing electromagnets for use with alternate currents various considerations enter which do not enter into the design of electromagnets for use with continuous currents. Chief of these considerations are the self-inductive action of the windings, and the frequency of the alternation of the current.

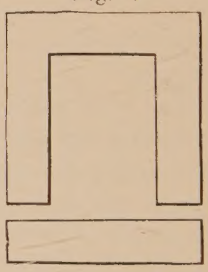
As with continuous-current electromagnets, so with alternate-current magnets, the degree to which magnetization is carried in the magnetic circuit of given configuration depends upon the number of ampere-turns of the excitation. The methods of predetermining the number needed to produce any desired degree of magnetization are too well known to need any reference. Our present aim is to show how to determine the winding which will, under given circumstances as to frequency, voltage, &c., produce any desired number of ampere-turns.

2. As a preliminary, however, it is needful to touch upon the point whether an electromagnet (properly laminated, it is understood) will give an equal pull, when excited with an equal number of ampere-turns of alternating current.

* Read April 27, 1894.

Since the pull of an electromagnet upon its armature depends upon the normal tension along the magnetic field integrated over the area of the pole-face, and this tension is proportional to the square of the intensity of the magnetic flux, then, if this flux were proportional to the number of ampere-turns of excitation (as would be the case if the permeability were constant), the pull would be proportional to the square of the number of ampere-turns. Now the ampere-meters for alternate currents operate upon principles that cause them to indicate the square root of the mean square values of the current. Hence it follows that, if permeability were constant, the pull should be proportional to the square of the current, whether the current be continuous or alternating. But since, with an alternating current of the same nominal value as a continuous current, the magnetism is carried at each period to a point considerably higher than with the continuous current, and since also at the higher degrees of magnetization the permeability is lower, it follows that the pull of the electromagnet when excited by alternate currents ought to be slightly less if the excitation is so great as to carry the magnetization into the regions commonly spoken of as approaching saturation. The pull ought to be independent of the frequency of the alternation provided this exceeds a certain minimum.

Fig. 1.



Experiments made show that these views are justified in practice.

An electromagnet of the form shown in fig. 1 was made up of iron stampings about 0·5 millim. thick.

The principal dimensions were as follows :—

| | | |
|---|---|---|
| Mean length of limbs and yoke . | 38 | cms. |
| Breadth of limb . . . . . | 3·1 | cms. |
| Gross thickness of limb . . . | 2·54 | cms. |
| Nett thickness of limb . . . . | 2·1 | cms. |
| Nett cross section of limb. . . | 6·5 | sq. cms. |
| Width between limbs . . . . | 6·3 | cms. |
| Total length of armature . . . | 12·7 | cms. |

The stampings of the armature were of the same thickness, number, and breadth as those of the electromagnet. In the succeeding experiments the electromagnet was wound with 163 turns of copper wire 2·03 millim. in diameter, and the armature was separated from the pole-faces by a distance-piece of wood 0·952 centim. thick.

TABLE showing Pull and Different Frequencies with various Currents.

| Exciting Current. Amperes. | Mean lines per sq. centimetre. | Pull, in grammes, with Continuous Current. | Pull, in grammes, with Alternate Current. |
|---|---|---|---|
| A. *At a frequency* | *of* 30 *periods per* | *second.* | |
| 8 | 2300 | 280 | 280 |
| 12·5 | 3600 | 820 | 820 |
| B. *At a frequency* | *of* 60 *periods per* | *second.* | |
| 8 | 2300 | 280 | 280 |
| 10·2 | 2900 | 530 | 550 |
| C. *At a frequency* | *of* 90 *periods per* | *second.* | |
| 4 | 800 | 60 | 60 |
| 4·2 | 1100 | 100 | 100 |
| 10·2 | 2900 | 530 | 530 |
| 21 | 5600 | 2400 | 2200 |
| D. *At a frequency* | *of* 120 *periods per* | *second.* | |
| 13·2 | 3900 | 900 | 900 |
| 21 | 5600 | 2400 | 2200 |

These experiments show that the pull was exactly the same when the intensity of the flux did not exceed 4000 lines per square centimetre. At higher degrees of magnetization the pull with alternate currents is slightly less.

It may be remarked that at higher intensities and with higher frequencies, eddy-currents, if any are present, will produce, for an equal flow of exciting current, a greater demagnetizing action, and therefore lessen the pull. On the other hand, if the current is supplied at a constant (alternating) voltage, eddy currents do not decrease the magnetization but cause more current to flow in proportion.

Another experiment was made with a solenoidal electromagnet with a laminated U-form plunger belonging to a Brush alternate-current arc-lamp. This plunger with attached mechanism weighed about 820 grammes, and was arranged to be drawn up into position by a current of 10 amperes. This plunger was loaded with various weights and the current required to raise it was measured, with the following results :—

| Total weight. Grammes. | Continuous Current. Amperes. | Alternate Current. Virtual Amperes. |
|---|---|---|
| 820 | 10 | 10 |
| 933 | 17·2 | 18 |
| 1039 | 18·2 | 19·5 |
| 1276 | 25 | 26·5 |
| 1601 | 31 | 33 |
| 1728 | 36 | 40 |

3. When alternate currents are supplied at a given voltage to an electromagnet having a given configuration of the magnetic circuit, and it is desired to produce by a winding any given number of ampere-turns of excitation, it is obvious that there are many ways of attaining the result with coils of various sizes and numbers of turns. If the resistance of the coil is so small relatively to the inductance as to be negligible, then there will only be one possible solution as to the number of turns. If, however, the resistance of the coil is of a magnitude comparable with that of its inductance, then there are various possible solutions, for an equal number of ampere-turns may be produced by using currents of different strengths and coils of different numbers of turns. In the cases of

different windings the lag of phase of the currents will be different. If the resistance is large relatively to the inductance, the difference of phase between the current and the impressed volts will be small, and the wasted watts large. If the inductance is large relatively to the resistance, the difference of phase will be nearly 90°; and the current will be nearly wattless, the efficiency being relatively high.

It is in accordance with good constructive practice to use such frequencies in the supply, and coils of such relatively high coefficients of self-induction as to justify the assumption, for the purpose of design, that the inductance is the important, and the resistance of the coil the unimportant matter. However, to bring the calculations to bear upon all cases that may occur, both resistance and inductance have been taken into consideration.

Let the impressed volts be called V, the current $i$ (both being square-root of mean square values), the resistance of the coil R, its coefficient of self-induction L, the frequency of the period of alternation $n$, and the number of windings W. The inductance will then be $2\pi n\mathrm{L}$, which for brevity may be written $p\mathrm{L}$. Then the impedance will be $\sqrt{\mathrm{R}^2+p^2\mathrm{L}^2}$. The relation between volts and amperes in the coil will be expressed as

$$\mathrm{V}=i\sqrt{\mathrm{R}^2+p^2\mathrm{L}^2}.$$

The angle of lag being called $\phi$, its sine will have the value

$$p\mathrm{L}\div\sqrt{\mathrm{R}^2+p^2\mathrm{L}^2}.$$

Hence we have the following relation :—

$$\mathrm{V}\,.\sin\phi=ip\mathrm{L}\,;\quad .\quad .\quad .\quad .\quad .\quad .\quad (1)$$

these being equivalent expressions for the effective part of the volts that is employed to balance the counter-electromotive force of self-induction in the coils. Now L is proportional to the square of the number of windings; and may be written $=k\mathrm{W}^2$, where $k$ is the coefficient of self-induction of a single turn, and W the number of windings.

Now, let the prescribed number of ampere-turns that are to be produced be called $\mathrm{Z}=i\mathrm{W}$. Inserting these values in (1) we obtain the expression

$$\mathrm{V}\sin\phi=kp\mathrm{WZ}\,;\quad .\quad .\quad .\quad .\quad .\quad .\quad (2)$$

and finally $$W = \frac{V \sin \phi}{kpZ}; \quad \ldots \ldots \quad (3)$$

which is the relation sought.

4. The quantity $k$ denoted above, the coefficient of self-induction of a single turn, depends upon the dimensions of the iron parts of the magnetic circuit and upon those of the air-gap, as well as upon the permeability of the iron. If the magnetization is not carried beyond 5000 lines per square centimetre, the permeability may be considered as constant. But $k$ will decrease with any increase in the reluctance of the magnetic circuit, such as the lengthening of the air-gap. On the contrary, as the armature is attracted up toward the poles $k$ increases. The quantity $k$ represents the number of magnetic lines ($\times 10^{-9}$) which permeate the magnetic circuit when one ampere circulates in a single turn of wire around the core. We have only to multiply $k$ by the square of the number of windings to obtain the coefficient of self-induction of any coil subsequently to be wound upon this magnetic circuit. The quantity $k$ must itself be experimentally determined. This can be done by winding upon the magnetic circuit an experimental coil having a known number of turns $w$, and a known resistance $r$. Using this coil, measure the virtual current $c$ which passes when it is supplied at a voltage $v$ of frequency $n$. During the experiment the armature should be fixed, say by wooden distance-pieces, in the position which it will occupy in use. Then the coefficient of self-induction $l$ of the temporary coil will be

$$l = \sqrt{v^2 - c^2 r^2} \div \sqrt{4\pi^2 n^2 c^2}.$$

Then $l$ being thus experimentally determined, it follows that $k = l/w^2$.

From the equation (3) we see that V, $p$, and $k$ being constant, there is a certain maximum number of windings which must not be exceeded if we are to get the prescribed number of ampere-turns of excitation; for $\sin \phi$ cannot be greater than unity. If this maximum number of windings is exceeded, the result will be to give fewer ampere-turns. This is easily seen if equation (3) be put into the form

$$Z = \frac{V \sin \phi}{kpW}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Other things being equal, *the ampere-turns are inversely proportional to the number of windings*. This, at first sight, seems an anomaly; but is easily understood when we remember that the self-induction, and therefore the lessening of the current, is proportional to the square of the number of turns; so that whilst we are increasing our turns we are reducing our amperes in a much greater ratio.

Having ascertained $k$, the only other factor to be determined is $\sin \phi$. This in most practical cases can be assumed to be unity, since with the usual frequencies of supply and using magnets with iron cores, there is no difficulty in keeping the resistance negligibly small even when the number of windings is at the required maximum, so that $\phi$ is very nearly 90°. This will be seen from the results given below obtained from an actual magnet. In most ordinary cases, then, we merely write

$$W = V/kpZ; \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

and, having calculated W, we find what current the wire will have to carry from the equation $i = ZW$. If there is room, and in most cases there will be ample, we may wind with thicker wire than is necessary to carry the current; but there is no advantage in using thicker wire than such as makes R practically negligible.

5. The following results are from actual experiment. The core and armature were those already described in relation to fig. 1. The iron core was wound with 140 turns of copper wire, 1·22 millim. in diameter, for the purpose of first determining $k$ when the armature was at the distances of 9·52, 6·35, 3·17, and 0 millim., respectively, from the poles. The resistance of the wire when heated by carrying 12 amperes was 0·3 ohm, and the frequency 93 periods per second. The fourth and fifth columns are worked out from the formulæ given above; for instance, in the first case

$$l = \frac{\sqrt{(31)^2 - (12 \times 0{\cdot}3)^2}}{2\pi \times 93 \times 12} = 0{\cdot}00434,$$

$$k = \frac{0{\cdot}00434}{(140)^2} = 0{\cdot}221 \times 10^{-6}.$$

| Air-gap (millimetres). | Virtual Volts at terminals of coil. | Virtual Amperes. | Coefficient of Self-induction $l$. | Self-induction of one turn. $k$. |
|---|---|---|---|---|
| 9·52 | 31 | 12 | 0·00434 | $0·221 \times 10^{-6}$ |
| 6·35 | 35·6 | 12 | 0·005 | $0·225 \times 10^{-6}$ |
| 3·17 | 46·8 | 12 | 0·00658 | $0·336 \times 10^{-6}$ |
| 0 | 51 | 2·76 | 0·033 | $1·68 \times 10^{-6}$ |

Suppose it were now required to wind the iron core so as to obtain 2400 ampere-turns when the armature was distant 9·52 millim. from the poles, using 50 volts and the same frequency as before.

Taking the equation (5) we obtain :

$$W = \frac{50}{0·221 \times 10^{-6} \times 2 \times 3·1416 \times 93 \times 2400} = 163 \text{ (approx.)}.$$

Accordingly 163 turns of wire 2·03 millimetres in diameter were wound upon the core. The current found, under the above conditions, to flow through the coil was 14·9 amperes, as measured by a Siemens' electrodynamometer. This shows that the coil produced 2430 ampere-turns, the error being well within what may be expected when using commercial measuring-instruments.

Some other results obtained with this magnet are given below (table, p. 141).

6. An advantage of the alternate-current electromagnet is the greater constancy in the pull which it exerts over a given range. If supplied at constant voltage a fairly constant pull on the armature can be obtained over a considerable range. The reaction set up by the core tends to set up a back-electromotive force the limiting value of which is equal to the impressed voltage. If the resistance of the coil were actually zero and the magnetic leakage also negligible, this limiting value would be attained. Now suppose that when acting upon its armature at a distance the self-inductive reaction chokes the current down to a certain value, the magnetization of the core going round cycles between definite maxima.

| Air-gap (millimetres). | Virtual Volts. | Virtual Amperes. | Coefficient of self-induction. | Self-induction of one turn. |
|---|---|---|---|---|
| *Coil* 163 turns ; resistance (hot) 0·15 ohm. | | | | |
| 9·52 | 50 | 14·9 | 0·00574 | $0·216\times10^{-6}$ |
| 6·35 | 50 | 12 | 0·00714 | $0·268\times10^{-6}$ |
| *Coil* 274 turns ; resistance (hot) 0·6 ohm. | | | | |
| 9·52 | 50 | 5 | 0·01712 | $0·228\times10^{-6}$ |
| 6·35 | 50 | 4·4 | 0·0194 | $0·259\times10^{-6}$ |
| 3·17 | 50 | 3·5 | 0·0244 | $0·326\times10^{-6}$ |

Suppose the core to be drawn in nearer to the pole, the reluctance of the magnetic circuit is lessened, and fewer ampere-turns will suffice to produce an equal magnetization ; but because the reluctance is lessened the coefficient of self-induction is correspondingly increased, and the current choked in corresponding proportion. These two effects counterbalance one another, the magnetization going round cycles of practically the same amplitude as before. Hence the pull will be practically unchanged, save in so far as any change in the magnetic leakage at the different positions of the armature comes in to affect the question by weakening the field between the pole-faces and the armature. Were the pole-faces made relatively large so as to obviate the tendency to leakage and ensure the field being nearly uniform in the gap-spaces, the pull should be also very nearly constant throughout a range equal to at least one third of the breadth of the pole-face.

7. It is useful also to know the ratio between the different voltages that are needed, for a given electromagnet, to produce an equal number of ampere-turns with alternating and continuous electromotive forces.

Let $V_a$ stand for the alternating volts and $V_c$ for the

continuous volts which must be applied to the terminals of the coil in order to produce equal virtual amperes. Then

$$\frac{V_a}{V_c} = \frac{\sqrt{R^2+p^2L^2}}{R}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

When, as is generally the case, R is small compared with $p$L, we may take as a sufficient approximation

$$\frac{V_a}{V_c} = \frac{pL}{R}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

*The alternate voltage ratio is proportional to the frequency and to the time-constant of the electromagnet.*—For this ratio we may, on certain assumptions, find an expression in terms of the dimensions of the core and coil. Confining ourselves to the case where the magnetic circuit is closed, we may find the value of L as follows:—

Let $l_1$ be the length (in centimetres) of the iron magnetic circuit, $A_1$ its cross section, $v_1$ its volume, $m_1$ its mass in grammes, $\mu$ its permeability, and S the number of windings in the coil. Now $m_1 = 7{\cdot}79 v_1$. Then L (in henries) will be

$$L = 4\pi A_1 \mu S^2/10^9 l_1 = 4\pi v_1 \mu S^2/10^9 l_1^2 = 4\pi m_1 \mu S^2/7{\cdot}79 \times 10^9 l_1^2.$$

Assuming that B does not exceed 6000 lines per square centimetre, we may take for ordinary wrought-iron sheet $\mu = 2000$, and inserting this we obtain

$$L = S^2 m_1/310{,}000\, l_1^2.$$

Further, let $l_2$ be the mean length of one turn of the copper winding, $A_2$ the cross section of the copper wire, $k$ its conductivity (mhos per centimetre cube $= 10^6 \div 1{\cdot}63$), $v_2$ the volume of copper ($= SA_2 l_2$), and $m_2$ the mass of copper ($= 8{\cdot}8 v_2$). Then we have for the resistance of the coil

$$R = l_2 S/A_2 k = l_2^2 S_2^2/v_2 k = 8{\cdot}8 l_2^2 S_2^2/m_2 k.$$

Inserting these values for L and S we obtain:—

$$\frac{V_a}{V_c} = \frac{pL}{R} = \frac{2\pi n S^2 m_1}{310000 l_1^2} \times \frac{m_2 . 10^6}{8{\cdot}8 l_2^2 S^2}.$$

$$\frac{V_a}{V_c} = 1{\cdot}41 n \frac{m_1 m_2}{l_1^2 l_2^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

It is, however, doubtful, since the magnetic circuit contains two joints, whether so high a value as 2000 can be expected

in ordinary work for $\mu$. In that case the coefficient 1·41 will be lower. With the electromagnet described above, at a frequency $n=93$, and with the armature in contact, the coefficient was 0·6 instead of 1·41. This is tantamount to saying that the working permeability was only 850. As so arranged, L being 0·044, the inductance $p$L was 25·26 ohms, and R was 0·15 ohm. The alternate voltage ratio was therefore about 170.

As the armature was removed from proximity to the poles the self-induction, and therefore the impedance, fell, making the voltage ratio for equal currents lower. When the armature was at 3·17 millim. the voltage ratio fell to 34, and at 9·52 millim. to 21·5.

It was stated above that in ordinary cases the ratio $p$L/R might be taken instead of the more complete expression of equation (6). If it is desired to obtain a nearer approximation to $\sqrt{R^2+p^2L^2}/R$ than is afforded by simply neglecting the R under the square-root sign, we may take the value

$$\frac{V_a}{V_c}=\frac{pL}{R}+\frac{R}{2pL},$$

which, by reference to the preceding numerical instances, shows that the correcting term is really negligible, being in the first case, where $p$L/R was 170, only $\frac{1}{340}$, and in the last case, where $p$L/R was 21·5, only $\frac{1}{43}$, less than $\frac{1}{8}$ of 1 per cent.

8. Lastly, a very simple expression can be found for the number of windings, in terms of any desired mean value of the magnetic flux **N** in the iron. For if the iron of cross-section A is subjected to cycles of magnetization in which the mean value of the permeation is **B**, the mean flux is $\mathbf{N}=A\mathbf{B}$, and if the frequency be $n$ periods per second, the self-induced electromotive force in W windings surrounding the iron will be equal to $2\pi n W\mathbf{N}\div 10^8$ volts. If, then, the resistance is negligibly small, this may be equated to V, the mean volts of supply, whence we obtain at once

$$W=\frac{V\times 10^8}{p\mathbf{N}}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

For example :—Suppose that in the above magnet it were desired to obtain a permeation of 4000 lines to the square

centimetre, the total number of lines **N** would equal the area A (6·5 square centim.) multiplied by 4000, or **N**=26,000. Taking the volts as 50, and the periods per second as 93, we find by formula (9), W=329.

## Discussion.

Prof. Perry pointed out that the constant pull of the alternate-current magnet followed immediately from the fundamental equation $e=rc+n\dot{\mathrm{I}}$, where $rc$ is small, for if $e$ be constant then $\dot{\mathrm{I}}$ and therefore I and $\mathrm{I}^2$ are constant. He was interested to see that the pulls for equal ampere-turns were the same, and indicated how the problem could be worked out mathematically when hysteresis was taken into account.

Mr. Blakesley thought it better to fill the space on a magnet full of copper rather than use wire only just large enough to carry the current, for the loss of energy would be reduced. Some of the formulæ given might be put in simpler form.

Mr. Swinburne said an alternate-current magnet would only give constant pull in special cases. As another rule for winding alternate-current magnets, he said, wind the magnets as for continuous currents, and put a condenser in to take the same current, thereby reducing the voltage required.

Mr. Blakesley said it would require a capacity of 600 microfarads to suit the magnet mentioned in the paper.

Dr. Thompson, in reply, agreed with Mr. Blakesley that the condenser was impracticable in many cases.

## XV. *On Electromagnetic Induction in Plane, Cylindrical, and Spherical Current-Sheets, and its Representation by Moving Trails of Images.* *By* G. H. Bryan, *M.A.**

### Part I.—General Equations—Plane Sheets.

*Introduction.*

1. It is well known that if a very thin, indefinitely extended plane sheet of metal of finite conductivity is placed in a varying magnetic field due to the presence of moving magnetic poles in its neighbourhood, induction-currents are set up in the sheet and the field of force due to these currents may be represented by a moving trail of images.

In the present paper the surface-conditions which hold at the surface of a plane, cylindrical, spherical, or other conducting sheet of uniform small thickness are deduced directly from the fundamental laws of electromagnetic induction. By working directly with the scalar magnetic potential, and avoiding the introduction of the vector potential and the quantity which Maxwell denotes by P, the investigations are much simplified. Moreover, in at least one comparatively recently published paper the boundary conditions satisfied by the vector potential at the surface of separation of two different media have been erroneously stated, and for this reason it is advantageous to employ a method which obviates the difficulty.

The results will be employed to show how the field due to the presence of a magnetic pole of varying intensity in the neighbourhood of a plane, cylindrical, or spherical current-sheet may be represented by means of a moving trail of images. By the principle of superposition the effect of any number of poles of varying intensity can be deduced, and the corresponding expressions for the field can thus be obtained when the variable inducing system of magnets is of the most general possible character, as, for example, one (or more) magnetic poles moving about in any manner whatever.

In this way a synthetic solution of the problem of induction

* Read May 11, 1894.

in current sheets is obtained. The phenomena of induction in spherical and other current sheets have been treated at considerable length from an analytical point of view by Larmor, Lamb, and Niven, and the last-named writer has made some attempt, in the case of a sphere, to interpret the results by means of images ; but the present investigation seemed desirable for many reasons, and it is hoped that it will overcome some of the difficulties, and elucidate some of the obscurities which present themselves in most treatments of this interesting application of the principles of electromagnetism.

*Fundamental Assumptions.*

2. The laws of electromagnetic induction assert that in bodies at rest

I. *The total current across any enclosed portion of a surface which always contains the same particles is equal to* $1/4\pi$ *of the line-integral of magnetic force round the curve bounding the surface.*

II. *The rate of decrease of the surface-integral of magnetic induction across any enclosed surface which always contains the same particles is equal to the line-integral of electromotive force round the curve bounding the surface.*

In applying these laws to an infinite dielectric separated into two portions by a thin conducting sheet, it is usually assumed that the disturbance produced by the inducing system is not a very rapidly alternating one, so that displacement currents in the dielectric have no appreciable magnetic effect*. With this assumption, the magnetic force in the dielectric will always be derivable from a potential which will only depend on the inducing system and the currents in the sheet. In other words, the state of the dielectric will be given by an "equilibrium theory."

It is also assumed that the induction-currents at any point distribute themselves uniformly throughout the thickness of the sheet. This requires that the disturbance shall not be a very rapidly alternating one, and also that the thickness of the sheet shall be very small compared with the other linear

* Watson and Burbury, 'Mathematical Theory of Electricity and Magnetism,' ii. § 405.

dimensions of the system (such as the distances of the moving poles, the radius of the sheet if spherical, &c.).

*Surface Conditions at a Plane-Current Sheet.*

3. Let the plane of the sheet be taken as the plane of $x$, $y$, let the thickness of the sheet be $c$, and specific conductivity C.

Let $\Omega_1$, $\Omega_2$ be the magnetic potentials on the negative and positive side of the sheet respectively, $\phi$ the current function in the sheet at any point. Apply Law I. to the circuit formed by going along the positive side of the sheet from the origin to any point and returning along the negative side from that point to the origin. Since the thickness of the sheet is small, the terms contributed to the line-integral of the magnetic force by the passage of the circuit from one side of the sheet to the other may be neglected and we obtain *

$$\Omega_2 - \Omega_1 = 4\pi\phi + \text{constant}. \quad . \quad . \quad . \quad . \quad (1)$$

Now apply Law II. to any circuit $s$ drawn in the plane of the sheet. Let $S_1$, $S_2$ be two surfaces drawn in the dielectric infinitely near to the positive and negative faces of the sheet respectively and both bounded by the curve $s$, and let P, Q be the components of electromotive force at any point. Then, assuming the magnetic permeability of the dielectric to be unity, we have

$$\int (P dx + Q dy) \text{ round } s = \frac{d}{dt}\iint \frac{d\Omega_1}{dz} dS_1 = \frac{d}{dt}\iint \frac{d\Omega_2}{dz} dS_2,$$

and since corresponding elements of the near surfaces $S_1$, $S_2$ are equal, it is evident that

$$\frac{d\Omega_1}{dz} = \frac{d\Omega_2}{dz} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

at the surface, so that the normal component of magnetic induction is continuous, as it should be †.

* Maxwell, 'Electricity and Magnetism,' ii. § 653.

† The magnetic permeability of the sheet itself will not affect the conditions of the problem unless it is required to proceed to a higher order of approximation by taking into account first powers of the thickness (or unless the sheet is formed of soft iron whose magnetic permeability may be large).

Again, the equations of conduction give

$$CcP = \frac{d\phi}{dy}, \quad CcQ = -\frac{d\phi}{dx}.$$

Hence

$$\frac{d}{dt}\iint \frac{d\Omega_1}{dz} dS = \frac{d}{dt}\iint \frac{d\Omega_2}{dz} dS = \frac{1}{Cc}\int\left(\frac{d\phi}{dy}\frac{dx}{ds} - \frac{d\phi}{dx}\frac{dy}{ds}\right)ds$$

$$= -\frac{1}{Cc}\int\left(\frac{d\phi}{dy}\frac{dy}{dn} + \frac{d\phi}{dx}\frac{dx}{dn}\right)ds = -\frac{1}{Cc}\int\frac{d\phi}{dn}ds$$

$$= -\frac{1}{Cc}\iint\left(\frac{d^2\phi}{dx^2} + \frac{d^2\phi}{dy^2}\right)dS,$$

where $dn$ is the element of the outward-drawn normal to $s$ and the surface-integral taken over the area S of the sheet bounded by the curve $s$.

Hence at the surface of the sheet

$$\frac{d}{dt}\frac{d\Omega_1}{dz} = \frac{d}{dt}\frac{d\Omega_2}{dz}$$

$$= -\frac{1}{Cc}\left(\frac{d^2\phi}{dx^2} + \frac{d^2\phi}{dy^2}\right)$$

$$= -\frac{1}{4\pi Cc}\left(\frac{d^2}{dx^2} + \frac{d^2}{dy^2}\right)(\Omega_2 - \Omega_1) \qquad \text{by (1)}$$

$$= \frac{1}{4\pi Cc}\frac{d^2}{dz^2}(\Omega_2 - \Omega_1) \quad . \quad . \quad . \quad . \quad . \quad (3)$$

(remembering that $\nabla^2\Omega_1 = 0$ and $\nabla^2\Omega_2 = 0$).

4. Now let $\Omega_0$ be the magnetic potential due to the external or inducing system, $\Omega'$ and $\Omega''$ the magnetic potentials on the two sides due to the sheet itself, so that

$$\Omega_1 = \Omega_0 + \Omega', \quad \Omega_2 = \Omega_0 + \Omega''. \quad . \quad . \quad . \quad (4)$$

Then $\Omega_0$ and its differential coefficients with respect to $z$ are continuous in crossing the sheet, while from the symmetry of the field due to the sheet

$$\Omega'(x, y, z) = -\Omega''(x, y, -z), \quad . \quad . \quad (5)$$

so that

$$\frac{d^n\Omega'}{dz^n} = (-1)^{n+1}\frac{d^n\Omega''}{dz^n}.$$

Therefore the surface condition (3) gives

$$\frac{d}{dt}\frac{d\Omega'}{dz}+\frac{d}{dt}\frac{d\Omega_0}{dz}=-\frac{1}{2\pi Cc}\frac{d^2\Omega'}{dz^2}, \quad . \quad . \quad . \quad (6)$$

$$\frac{d}{dt}\frac{d\Omega''}{dz}+\frac{d}{dt}\frac{d\Omega_0}{dz}=+\frac{1}{2\pi Cc}\frac{d^2\Omega''}{dz^2} \quad . \quad . \quad . \quad (7)$$

as the surface conditions satisfied by the potential at the two sides of the sheet.

*Surface Conditions at a Cylindrical Sheet.*

5. Using cylindrical coordinates, let $r=a$ be the equation of the middle surface of a cylindrical current-sheet, and let its thickness $c$ be so small that the corresponding elements of its bounding surfaces and middle surface, viz.

$$(a-\tfrac{1}{2}c)\,d\theta dz,\ (a+\tfrac{1}{2}c)\,d\theta\,dz, \text{ and } a\,d\theta dz,$$

are to be regarded as equal.

If $\Omega_1$, $\Omega_2$ are the magnetic potentials inside and outside the sheet, we shall still have as for a plane sheet

$$\Omega_2-\Omega_1=4\pi\phi+\text{constant}; \quad . \quad . \quad . \quad . \quad (1)$$

and by application of the second law to the small circuit bounding the surface-element $a\,d\theta dz$, we have at the sheet

$$\begin{aligned}\frac{d}{dt}\frac{d\Omega_1}{dr}=\frac{d}{dt}\frac{d\Omega_2}{dr}&=-\frac{1}{Cc}\left\{\frac{d}{rd\theta}\frac{d\phi}{rd\theta}+\frac{d^2\phi}{dz^2}\right\}\\&=-\frac{1}{4\pi Cc}\left\{\frac{1}{r^2}\frac{d^2}{d\theta^2}+\frac{d^2}{dz^2}\right\}(\Omega_2-\Omega_1)\\&=\frac{1}{4\pi Cc}\left(\frac{d^2}{dr^2}+\frac{1}{r}\frac{d}{dr}\right)(\Omega_2-\Omega_1),\end{aligned}$$

or

$$\frac{d}{dt}\left(r\frac{d\Omega_1}{dr}\right)=\frac{d}{dt}\left(r\frac{d\Omega_2}{dr}\right)=\frac{1}{4\pi Cc}\frac{d}{dr}r\frac{d}{dr}(\Omega_2-\Omega_1). \quad . \quad . \quad (8)$$

*Surface Conditions at a Spherical Sheet.*

6. In the case of a spherical sheet of small thickness, we obtain in like manner

$$\frac{d}{dt}\frac{d\Omega_1}{dr}=\frac{d}{dt}\frac{d\Omega_2}{dr}=\frac{1}{4\pi Cc}\left(\frac{d^2}{dr^2}+\frac{2}{r}\frac{d}{dr}\right)(\Omega_2-\Omega_1),$$

or

$$\frac{d}{dt}\left(r^2\frac{d\Omega_1}{dr}\right)=\frac{d}{dt}\left(r^2\frac{d\Omega_2}{dr}\right)=\frac{1}{4\pi Cc}\frac{d}{dr}r^2\frac{d}{dr}(\Omega_2-\Omega_1). \quad (9)$$

*Extension to Curved Sheets of other Forms.*

7. When the sheet is of any form other than those above considered, it is necessary to assume a certain law of variation of the thickness in order to put the boundary conditions into a form similar to those given above *.

Let us use orthogonal coordinates $\alpha$, $\beta$, $\gamma$; let the line-element be given by

$$ds^2 = \frac{d\alpha^2}{h_1^2} + \frac{d\beta^2}{h_2^2} + \frac{d\gamma^2}{h_3^2},$$

and let the equation of the current sheet be

$$\gamma = \text{constant}.$$

Equation (1) still holds, and by applying Law II. to the circuit enclosed on the sheet by the curves $\alpha$, $\alpha+\delta\alpha$, $\beta$ and $\beta+\delta\beta$, we have the surface-condition

$$\frac{1}{h_1 h_2}\frac{d}{dt} h_3 \frac{d\Omega_1}{d\gamma} = \frac{1}{h_1 h_2}\frac{d}{dt} h_3 \frac{d\Omega_2}{d\gamma}$$

$$= -\frac{d}{d\alpha}\left\{\frac{h_1}{Cch_2}\frac{d\phi}{d\alpha}\right\} - \frac{d}{d\beta}\left\{\frac{h_2}{Cch_1}\frac{d\phi}{d\beta}\right\}$$

$$= -\frac{1}{4\pi}\left\{\frac{d}{d\alpha}\left(\frac{h_1}{Cch_2}\frac{d}{d\alpha}\right) + \frac{d}{d\beta}\left(\frac{h_2}{Cch_1}\frac{d}{d\beta}\right)\right\}(\Omega_2 - \Omega_1). \quad (10)$$

But Laplace's equation which is satisfied by $\Omega_1$ $\Omega_2$ may be written

$$\frac{d}{d\alpha}\left(\frac{h_1}{h_2 h_3}\frac{d\Omega}{d\alpha}\right) + \frac{d}{d\beta}\left(\frac{h_2}{h_3 h_1}\frac{d\Omega}{d\beta}\right) + \frac{d}{d\gamma}\left(\frac{h_3}{h_1 h_2}\frac{d\Omega}{d\gamma}\right) = 0.$$

Hence it is possible to eliminate differential coefficients with respect to $\alpha$, $\beta$ from the surface-condition if, and only if,

$$Cc \propto h_3. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Hence the thickness of the sheet at any point must be inversely proportional to the distance between two neighbouring surfaces of the family $\gamma = \text{constant}$ at that point. In the case of an ellipsoidal sheet this leads to the well-known condition that the thickness must be proportional to the perpen-

* Compare Watson and Burbury, §426.

dicular on the tangent-plane, or that the sheet must be a shell bounded by similar and similarly situated ellipsoids.

Writing

$$\mathrm{R}=\frac{h_3}{2\pi \mathrm{C}c}, \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

the surface-condition now becomes

$$\frac{d}{dt}\left(\frac{h_3}{h_1h_2}\frac{d\Omega_1}{d\gamma}\right)=\frac{d}{dt}\left(\frac{h_3}{h_1h_2}\frac{d\Omega_2}{d\gamma}\right)=\frac{\mathrm{R}}{2}\frac{d}{d\gamma}\left\{\frac{h_3}{h_1h_2}\frac{d}{d\gamma}(\Omega_2-\Omega_1)\right\} \quad (13)$$

*Synthetic Determination of the Images in a Plane Sheet.*

8. In order to illustrate the synthetic method, consider its application to the well-known case of a plane-current sheet. Let the induced currents be excited by a magnetic pole placed at the fixed point $(x_0, y_0, z_0)$ on the positive side of the sheet whose strength is $f(t)$ an arbitrary function of the time. Then

$$\Omega_0=\frac{f(t)}{\{(x-x_0)^2+(y-y_0)^2+(z-z_0)^2)\}^{\frac{1}{2}}}, \quad . \quad . \quad (14)$$

and the surface-condition satisfied by $\Omega'$ the potential on the negative side is

$$\frac{d^2\Omega'}{dzdt}+\mathrm{R}\frac{d^2\Omega}{dz^2}=-\frac{d^2\Omega_0}{dzdt}, \quad . \quad . \quad . \quad . \quad (15)$$

where

$$\mathrm{R}=\frac{1}{2\pi \mathrm{C}c}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

Integrating (15), the value obtained for $\Omega'$ is found to be the potential due to magnetic poles or images on the positive side of the sheet, and these are outside the region over which the solution is required to hold, as they should be. We have

$$\left(\frac{d}{dt}+\mathrm{R}\frac{d}{dz}\right)\Omega'=-\frac{f'(t)}{\sqrt{\{(x-x_0)^2+(y-y_0)^2+(z-z_0)^2\}}},$$

$$\therefore \quad \Omega'=-\int_{-\infty}^{t} e^{-\mathrm{R}(t-\tau)\frac{d}{dz}}\frac{f'(\tau)}{\sqrt{\{(x-x_0)^2+(y-y_0)^2+(z-z_0)^2\}}}d\tau$$

$$=-\int_{-\infty}^{t}\frac{f'(\tau)}{\sqrt{\{(x-x_0)^2+(y-y_0)^2+(z-z_0-\mathrm{R}t+\mathrm{R}\tau)^2\}}}d\tau$$

$$=-\frac{f(t)}{\sqrt{\{(x-x_0)^2+(y-y_0)^2+(z-z_0)^2\}}}$$

$$+\int_{-\infty}^{t}\mathrm{R}f(\tau)\frac{d}{dz}\frac{1}{\sqrt{\{(x-x_0)^2+(y-y_0)^2+(z-z_0-\mathrm{R}t+\mathrm{R}\tau)^2\}}}d\tau. \quad (17)$$

The first term represents the effect of a pole equal and opposite to the given pole at the point $(x_0, y_0, z_0)$, while the second term shows that the effect of the action of the pole between the times $\tau$ and $\tau+\delta\tau$ is represented at time $t$ by a magnet of strength $\mathrm{R}f(\tau)\delta\tau$ situated at the point $(x_0, y_0, z_0+\mathrm{R}(t-\tau))$. The potential at the positive side is found from the relation (5), or

$$\Omega''(x, y, z) = -\Omega'(x, y, -z).$$

When the pole is in motion the results thus arrived at enable us to plot out the moving images contributed during every time element $\delta\tau$ of the motion in the well-known way, or they may be obtained as follows :—

9. If, instead of a single magnetic pole, we are dealing with a magnetic distribution on the positive side of the sheet such that the volume-density of magnetism of the point $(x_0\, y_0\, z_0)$ is $\mathrm{F}(x_0\, y_0\, z_0\, t)$, we must write $\mathrm{F}(x_0\, y_0\, z_0\, t)\, dx_0\, dy_0\, dz_0$ for $f(t)$ in the expressions for $\Omega_0$ and $\Omega'$. Hence we have

$$\Omega_0 = \int_0^\infty \int_{-\infty}^\infty \int_{-\infty}^\infty \frac{\mathrm{F}(x_0\, y_0\, z_0\, t)\, dx_0\, dy_0\, dz_0}{\{(x-x_0)^2+(y-y_0)^2+(z-z_0)^2\}^{\frac{1}{2}}}, \quad . \quad . \quad . \quad (18)$$

$$\Omega' = -\Omega_0 - \int_{-\infty}^t d\tau \int_0^\infty dz_0 \int_{-\infty}^\infty \int_{-\infty}^\infty \mathrm{R}\mathrm{F}(x_0\, y_0\, z_0\, \tau) \frac{z-z_0-\mathrm{R}(t-\tau)}{\{(x-x_0)^2+(y-y_0)^2+(z-z_0-\mathrm{R}(t-\tau))^2\}^{\frac{3}{2}}} dx_0\, dy_0. \quad (19)$$

If now the inducing system consists of a single pole of strength $f(t)$ which moves about *in any manner* so that its coordinates at any time $t$ are $\xi(t)$, $\eta(t)$, $\zeta(t)$, functions of $t$, we have

$$\mathrm{F}(x_0\, y_0\, z_0\, \tau) = 0,$$

except when $x_0=\xi(\tau)$, $y_0=\eta(\tau)$, $z_0=\zeta(\tau)$, and then

$$\mathrm{F}(x_0\, y_0\, z_0\, \tau)\, dx_0\, dy_0\, dz_0 = f(\tau).$$

Therefore

$$\Omega_0 = \frac{f(t)}{\{(x-\xi(t))^2+(y-\eta(t))^2+(z-\zeta(t))^2\}^{\frac{1}{2}}}, \quad . \quad . \quad . \quad . \quad (20)$$

$$\Omega' = -\Omega_0 - \int_{-\infty}^t \mathrm{R}f(\tau) \frac{z-\zeta(\tau)-\mathrm{R}(t-\tau)}{\{(x-\xi(\tau))^2+(y-\eta(\tau))^2+(z-\zeta(\tau)-\mathrm{R}(t-\tau))^2\}^{\frac{3}{2}}} d\tau. \quad (2$$

This is the expression for the magnetic potential due to the induced currents on the negative side of the sheet, *i. e.* on the opposite side to the moving pole; and it is to be observed that $z$ is taken to be negative on this side.

The quantity $\Omega''$, which represents the potential due to the induced currents on the positive side (where $z$ is positive), is given by

$$\Omega'' = \frac{f(t)}{\{(x-\xi(t))^2+(y-\eta(t))^2+(z+\zeta(t))^2\}^{\frac{1}{2}}} - \int_{-\infty}^{t} \mathrm{R} f(\tau) \frac{z+\zeta(\tau)+\mathrm{R}(t-\tau)}{\{(x-\xi(\tau))^2+(y-\eta(\tau))^2+(z+\zeta(\tau)+\mathrm{R}(t-\tau))^2\}^{\frac{3}{2}}} d\tau \quad (22)$$

and the complete expression for the potential due to the induced currents and the moving pole itself is, by (4),

$$\Omega_2 = \Omega_0 + \Omega''.$$

10. The components of magnetic force at $(x, y, z)$ due to the induced currents alone are respectively

$$-\frac{d\Omega''}{dx}, \quad -\frac{d\Omega''}{dy}, \quad -\frac{d\Omega''}{dz};$$

and the components of the force on the pole itself at any time $t$ are found by multiplying these expressions by the strength of the pole, *i. e.* by $f(t)$, and putting $x=\xi(t)$, $y=\eta(t)$, $z=\zeta(t)$ *after* the differentiations have been performed.

In particular, if the pole moves along a straight line perpendicular to the plate, and we take this line as axis of $z$, the force on the moving pole itself

$$= f(t) \times \left\{ \frac{f(t)}{\{2\zeta(t)\}^2} - 2\,\mathrm{R} \int_{-\infty}^{t} \frac{f(\tau)\, d\tau}{\{\zeta(t)+\zeta(\tau)+\mathrm{R}(t-\tau)\}^3} \right\}. \quad (23)$$

The well-known case in which a pole is suddenly generated at the time $t=0$, and its strength remains constant and equal to $m$ after that time, is deduced by making

$$f(t)=0 \quad \text{from } t=-\infty \text{ to } t=0,$$

$$f(t)=m \quad \text{from } t=0 \text{ to } t=+\infty.$$

We therefore have to write $m$ for $f(t)$ in the above expressions and to reduce the inferior limit of integration with respect to $\tau$ from $-\infty$ to 0.

The advantage of starting with a fixed instead of a moving pole is more evident in the case of a cylindrical or spherical sheet, especially in the latter, since we are thus enabled to use zonal spherical harmonics only and the analysis is consequently much simplified.

## Discussion.

Prof. Minchin showed that equation (1) of the paper ($\Omega_2 - \Omega_1 = 4\pi\phi +$ constant, where $\Omega_2$ and $\Omega_1$ are the magnetic potentials at the two sides of the sheet, and $\phi$ the current function) could be deduced by purely mathematical reasoning, instead of being based on the laws of electromagnetic induction. Moreover it was true of any function whatever, and did not depend on $\phi$ being the current function. Equation (2),

$$\left(\frac{d\Omega_2}{dz} = \frac{d\Omega_1}{dz}\right),$$

followed immediately from the fact that the magnetic force was continuous. The latter part of the paper might be simplified by integrating the linear partial differential equation (15)

$$\left(\frac{d^2\Omega_1}{dz\,dt} - \mathrm{R}\frac{d^2\Omega_1}{dz^2} = -\frac{d_2\Omega_0}{dz\,dt}\right)$$

in the ordinary way, for the form was one for which the auxiliary equations are well known.

Dr. Burton, in reply, said he thought Mr. Bryan's reason for developing the equations from the laws of electromagnetic induction was to give his work a physical rather than a mathematical basis.

## XVI. *On Dielectrics.* *By* Rollo Appleyard *.

Most dielectrics, when submitted to the ordinary "insulation" test, show an apparent increase of resistance under the action of the testing-current. That is to say: from the moment the current has been applied, the galvanometer-spot, having reached its maximum position, falls gradually towards zero with time. The rate of this diminution, at any instant, is a measure of the so-called "electrification" of the dielectric at that instant. For commercial purposes the "electrification" is usually computed between the first and second minutes from the moment of charge; the value thus determined is an excellent confirmatory guide to quality, if the general history of the material and the peculiarities of manufacture are understood. But, apart from its merely commercial bearing, "electrification" presents a wide field for scientific research. The use of the term "electrification" for this rate of change of the apparent resistance of a dielectric with the time of application of the charging current, may be called into question by those who prefer the words "polarization," or "absorption;" but, in the present stage of our knowledge of the action which determines this change, it has been thought better to adopt a term which is never mistaken in practice than to use an ambiguous expression, founded upon an equally uncertain hypothesis. "Electrification" seems to be the net result of many simultaneous actions, some of which are very obscure; the physical mechanism implied in the process is subtle and mysterious, the experimental observations are difficult to reconcile among themselves, and there is no theory to adequately account for the phenomena. It is not proposed, here, to make any attempt at solving the difficulties, but rather to present them in the form of experimental results.

### *Celluloid.*

The first substance to be dealt with, in this regard, is "celluloid." As far as can be judged by inspection it appears to be a compound of guncotton and camphor, with a

* Read May 11, 1894.

trace of lime—possibly in the form of sulphate. When seen through the microscope, small white spots become visible in a translucent yellowish substance. In texture "celluloid" resembles "cordite," but it is of lighter colour, inflammable but not explosive. The insulation of this substance was, at first, measured in the following way :—A thin circular sheet of celluloid was placed between two plane surfaces of brass 11 inches in diameter. A margin of celluloid was allowed, to prevent leakage over the edges ; and a heavy weight was put upon the top plate. When this sheet was submitted to the action of a current, there was no such apparent increase of resistance as is usually to be observed with dielectrics. The galvanometer, in fact, indicated the reverse effect—the deflexion gradually increasing with time. No actual fault could be detected in any of the samples, and yet the "electrification" was negative. This curious effect was the more to be noticed as the voltage of the testing-battery was increased. The actual insulation resistance, calculated for the same sample, with this apparatus, under various currents, showed that the resistance changed enormously with the testing voltage.

In this case, and in all experiments here mentioned, the insulation has been computed from the deflexions obtained after the corresponding voltage had been applied for one minute. The upper readings correspond with increasing voltages ; the lower curve completes the cycle with diminishing voltages, and shows the falling-off of insulation with current, in a manner curiously like the hysteresis curve of iron. The observed values are given in Table I.

TABLE I.—Celluloid Sheet.

| | volts 150 | volts 300 | volts 600 | volts 750 | volts 600 | volts 300 | volts 150 |
|---|---|---|---|---|---|---|---|
| Galvanometer Readings. 1m... | 19·8 | 85·8 | 533 | 1310 | 605 | 152 | 45 |
| Galvanometer Readings. 2m... | 20 | 89·3 | 554 | 1338 | 663 | 158 | 45 |
| Corresponding Resistance in megohms. = | 4040 | 1840 | 597 | 303 | 526 | 1039 | 1778 |

This table includes the actual galvanometer-deflexions from which the insulation-resistance at each voltage was calculated. First and second minute readings are recorded, and exhibit very strikingly the apparently *negative* "electrification,"—the first-minute readings being less than the second-minute readings.

A series of tests was made upon celluloid sheets pressed, in the above manner, between two plane surfaces of metal, and the same general features were observed in each case. As no definite fault could be discovered in any sample, I was led to suppose that the abnormal change in resistance, and the corresponding negative "electrification," were to be accounted for by some complex molecular rearrangement within the substance of the celluloid itself. Leakage over the edges might obviously be urged in explanation, but the conditions did not seem to allow of any serious loss in this manner. While employing unyielding metallic surfaces against the comparatively hard surface of the celluloid, the chances of uneven pressure upon the sheet were very great: which would imply uneven electrical contact between the dielectric and the plates.

The next experiments were made with a view to test the celluloid in perfect contact with the opposed plates; to remove all chances of leakage-error; and to provide, at the same time, a more evenly distributed pressure over the surface. The hard metallic plates were therefore replaced by mercury surfaces which conformed precisely, and without undue pressure, to the sheet of dielectric; and, at the same time, made perfect contact with it, leaving no air-spaces or spark-gaps where ozone or other gases might collect.

Circular sheets of celluloid, $11\frac{1}{2}$ inches in diameter, were employed for these tests. To prevent leakage, a 3-inch margin was allowed all round, so that the working-surface in contact with mercury was $5\frac{1}{2}$ inches in diameter. The method of fixing the dielectric sheet was as follows:—Two flat ebonite rings, $5\frac{1}{2}$ inches internal diameter, and $6\frac{1}{2}$ inches outside, were faced on each side with india-rubber, forming insulating washers. These rings were placed exactly opposite each other, flatwise, one on each side of the sheet to be tested. Circular plates of iron were now laid against the outer faces

of the rings, and combined to make two mercury-tight hollow boxes, one on each side of the dielectric. The whole was then gripped vertically in an ebonite vice; after which mercury was poured in to fill the boxes. This apparatus, with the exception of the insulating rings, is the same as that designed, I believe, by Mr. Evers. The great advantage of the method is that the mercury conforms to the surface of the dielectric, leaving no air-spaces and necessitating no artificial pressure. The surface-leakage can be made as small as desired, by the simple device of leaving enough margin. Experiments made upon dielectrics fixed in this apparatus give results entirely different from those obtained with rigid metallic plates.

A sheet of celluloid ·071 inch in thickness was the first that came under trial. Its behaviour during a cycle of voltage from 150 to 1200 volts is represented in Table II.

TABLE II.

| Volts *increasing*. | | Volts *diminishing*. | |
|---|---|---|---|
| Volts. | Resistance in megohms. | Volts. | Resistance in megohms. |
| 150 | 82·7 | 1050 | 80·7 |
| 300 | 82·3 | 900 | 81·0 |
| 450 | 82·0 | 750 | 81·3 |
| 600 | 81·5 | 600 | 81·5 |
| 750 | 81·2 | 450 | 82·0 |
| 900 | 80·8 | 300 | 82·3 |
| 1050 | 80·6 | 150 | 82·7 |
| 1200 | 80·6 | | |

The curves practically overlap. The insulation falls somewhat with the increase of voltage, but recovers its original value as the cycle is completed. There was no observable "electrification"; the first and second minute readings were in each case identical.

The next sheet of celluloid tested was 6 mils in thickness. Here again there was no sign of "electrification," though there was a distinct diminution of insulation with voltage.

This sheet broke down at 1200 volts; there is nothing in the curve to indicate that such a rupture was about to take place. These results are given in Table III.

TABLE III.

| Volts *increasing*. | Resistance in megohms. |
|---|---|
| 150 | 30·0 |
| 300 | 29·6 |
| 450 | 29·2 |
| 600 | 28·4 |
| 750 | 27·7 |
| 900 | 26·8 |
| 1050 | 26·0 |
| 1200 | Broke down. |

A third sheet, cut from the same specimen as the last, was then tested through a cycle from 150 to 1050 volts; it showed practically no hysteresis and no "electrification," the return values being simply reproductions of the rising ones. There is the same drop in insulation with voltage as in the previous tests, as shown by Table IV.

TABLE IV.

| Volts *increasing*. | | Volts *diminishing*. | |
|---|---|---|---|
| Volts. | Resistance in megohms. | Volts. | Resistance in megohms. |
| 150 | 26·34 | 900 | 22·72 |
| 300 | 25·56 | 750 | 23·48 |
| 450 | 24·93 | 600 | 24·15 |
| 600 | 24·15 | 450 | 24·93 |
| 750 | 23·51 | 300 | 25·68 |
| 900 | 22·72 | 150 | 26·52 |
| 1050 | 21·89 | | |

The same sheet was then tested between hard metallic plates, the results are indicated in Table IV. A.

TABLE IV. A.

| | volts 150 | volts 300 | volts 450 | volts 600 | volts 750 | volts 900 | volts 1050 | volts 900 | volts 750 | volts 600 | volts 450 | volts 300 | volts 150 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1m | 6 | 23·5 | 61·5 | 161 | 278 | 156 | 158 | 186 | 127 | 117·0 | 95·0 | 32·5 | 11·5 |
| 2m | ..... | 23·7 | 64·0 | 171 | 296 | 162 | 162 | 189 | 129 | 118·5 | 96·5 | 39·5 | ..... |
| | megohms 20,550 | 10440 | 6047 | 3076 | 870 | 283 | 135 | 199 | 549 | 1641 | 3915 | 6212 | 10720 |

*"Dielectric Hysteresis."*

"Dielectric hysteresis" is here alluded to in a sense which needs a little explanation. The similarity in shape and character between some of these curves and the well-known forms of the hysteresis curves of magnetism is all that I wish to imply,—it is *not* the phenomenon of "dielectric hysteresis" proper. In an article in the *Electrotechnische Zeitschrift*, 29th April, 1892, p. 227, Steinmetz traces the analogy between a dielectric medium in an electrostatic field and magnetic bodies in a magnetic field, with a view to determining whether the loss of energy in dielectrics, under the influence of an alternating electrostatic field, would follow a law similar to that which defines the magnetic losses due to magnetic hysteresis. The experiments of Steinmetz, and of Arno, have gone to show that the energy expended in a dielectric medium, in an electrostatic field of alternating potential, is sensibly proportional to the square-root of the intensity of the electrostatic field. These losses are due to "dielectric hysteresis" proper, and are quite distinct from the mere change of resistance with voltage here described. The experimental results of Steinmetz should, however, be corrected for this other phenomenon of change, which, for the time being, we may call "dielectric mutability," or any other term which denotes the variation of resistance with voltage; for it is clear that the energy expended during a cycle of potential cannot rightly be calculated upon the basis of constant resistance assumed by Steinmetz. With this correction, if it could be determined and applied to his results,

the observed values, notwithstanding their present close agreement with those calculated, may possibly be brought even nearer to conformity.

### *"Residual Charge."*

The residual charge becomes a very small quantity a few minutes after breaking circuit; consecutive voltages can therefore be applied without having to wait very long for the practical disappearance of the last charge. In the above tests it was made a rule never to send a current into a sheet until the previous charge had vanished to within $\frac{1}{2}$ per cent. Although, under these conditions, the charge is quickly got rid of, yet during the first few seconds the amount left in may be very considerable. Conversely, the celluloid takes up its charge comparatively tardily. If, for instance, an attempt is made to determine the capacity of the sheet, when in the mercury apparatus, by the simple discharge method, an eye which is accustomed to watching the "throw" of the galvanometer will at once observe that the needle is under the action of an extended discharge and not of a sudden impulse. When first this phenomenon was observed I carried out the following experiment:—The celluloid was charged from 20 cells for 15 seconds. It was then discharged, not through the galvanometer, but through the short-circuit key. After two seconds the short-circuit key was opened, and there was a discharge of a few degrees to the right—that is, in the "discharge" direction; this fell in a few seconds across the zero to 5 divs. on the left, where it remained perfectly steady. This curious reversal of sign was at first rather puzzling; if the spot had merely fallen to zero, it would have been easy to refer it to complete loss of charge; if it had fallen a little to the right of zero, it could have been attributed to incomplete loss of charge; but falling, as it did, on the negative side of zero, a novel case was presented.

After several repetitions, charging with various potentials up to as high as 900 volts, this reversal still manifested itself, although the time required to attain it was of course greater as the testing-voltage increased. Days and nights of short-circuiting would not wipe it out; whatever was tried, it remained always the same negative deflexion. It is, in fact,

an initial permanent E.M.F. of about ·0006 of a volt with which nothing seems to interfere. It is apparently due to the contact of the mercury with the celluloid ; it did not appear when metallic plates were used. This point having been so far settled, the experiments on slow discharge were repeated with 100, 200, 400, and 600 cells ; the corresponding discharge-readings—after short-circuiting the sheet for two seconds in each case before discharge—were respectively 18, 36, 57, and 80 divs., falling to zero, or very nearly to zero in a few minutes, and ultimately crossing the zero to −5. The discharge from a standard microfarad charged to 30 volts is 11,103 scale-divs. The instantaneous discharge from the celluloid sheet ($5\frac{1}{2}$ in. diam., ·00615 inch thick) with the same voltage, was 115 divs., which is the mean of the two readings obtained by reversing the battery. The test can scarcely be regarded as a capacity test under the above conditions. It is recorded here simply to show the phenomenon of slow discharge, and the existence of the permanent initial E.M.F.

*Gutta-percha.*

Appended are the results of some tests upon a sheet of pure gutta-percha, in the mercury apparatus, at high voltages. The thickness of this sheet was about 2 mils ; the diameter of the circular mercury surface in contact with it, bounded by the insulating rings, was, as before, $5\frac{1}{2}$ inches. Curves drawn from the tabulated results exhibit the phenomenon of dielectric hysteresis, and show that the effect of the current, up to a certain point, is to increase the resistance ; there is a subsequent tendency in the opposite direction, which would probably end in the breaking-down of the sample. There was no initial electromotive force to be observed with the gutta-percha.

Four separate tests were made upon the sheet, two with a cycle commencing at maximum volts, and two commencing at the minimum. In each case, whether beginning at the maximum or minimum volts, there was a decided increase of resistance as the result of a cycle. With such a thin sheet as 2 mils the test was a very severe one for the gutta-percha ; hence it is not surprising that the curves are somewhat broken. Two-thousandths of an inch of material is here effectively contending against 1200 volts, and setting up a barrier of 3000 million ohms over an area of $5\frac{1}{2}$ inches.

A very interesting point about these four tests is that when the cycle commences at maximum voltage the subsequent readings are far steadier, and the curve of resistance and voltage smoother, than when minimum volts are started with; this is clearly indicated by a comparison of the four curves which may be drawn from these tables.

There is no absolute need to short-circuit the apparatus in order to remove the residual charge of the sheet; but short-circuiting probably quickens the process. This is a matter for further experiment. It was found that the sample of gutta-percha completely lost its charge after twenty-four hours, whether short-circuited or not, and during that time it regained its normal condition as regards insulation resistance. Twenty-four hours was therefore allowed between each of the four tests upon the gutta-percha sheet. As a rule, about ten minutes' rest was given between the consecutive voltages of individual tests; this was found to be time enough to practically discharge the sheet when short-circuited.

TABLE V.—Gutta-percha sheet ($G_2$).
(Volts *increasing*.)

| | volts 150 | volts 300 | volts 450 | volts 600 | volts 750 | volts 900 | volts 1050 | volts 1200 |
|---|---|---|---|---|---|---|---|---|
| 1m ... | 26·2 | 49·8 | 68·4 | 82 | unsteady 130 | unsteady 150 | unsteady 160 | steadier 171 |
| 2m ... | 25·6 | 47·6 | 65·0 | unsteady 98 | 117 | 135 | 160 | 159 |
| | 2272^ | 2384^ | 2614^ | 2910^ | 2290^ | 2383^ | 2602^ | 2789^ |

| | volts 1050 | volts 900 | volts 750 | volts 600 | volts 450 | volts 300 | volts 150 | volts 1200 |
|---|---|---|---|---|---|---|---|---|
| 1m ... | steady 126 | 100 | 73 | 53·5 | 38·5 | 24·5 | 12·0 | 170 |
| 2m ... | 126 | 100 | 75 | 49·0 | 31·0 | 18·0 | 9·2 | 148 |
| | 3303^ | 3572^ | 4079^ | 4459^ | 4645^ | 4845^ | 4961^ | 2805^ |

Temp. =66° F.

TABLE VI.—Gutta-percha sheet ($G_2$).
(Volts *diminishing*.)

| | volts 1200 | volts 1050 | volts 900 | volts 750 | volts 600 | volts 450 | volts 300 | volts 150 |
|---|---|---|---|---|---|---|---|---|
| 1m ... | steady 171·2 | 137·3 | 112·5 | 91·8 | 71·8 | 54·2 | 39 | 20·0 |
| 2m ... | 166·0 | 135·0 | 111·5 | 89·5 | 68·0 | 49·0 | 34 | 17·7 |
| | 3220~ | 3510~ | 3670~ | 3760~ | 3840~ | 3820~ | 3530~ | 3470~ |

| | volts 300 | volts 450 | volts 600 | volts 750 | volts 900 | volts 1050 | volts 1200 |
|---|---|---|---|---|---|---|---|
| 1m ... | 38·5 | 53·5 | 69·5 | 84 | 100 | 118·5 | steady 145 |
| 2m ... | 33·8 | 48·0 | 64·5 | 81 | 98 | a little unsteady 119·0 | 143 |
| | 3570~ | 3870~ | 3970~ | 4130~ | 4130~ | 4070~ | 3800~ |

23rd April, 1894. Temp. =64°·5 F.

TABLE VII.—Gutta-percha sheet ($G_2$).
(Volts *increasing*.)

| | volts 150 | volts 300 | volts 450 | volts 600 | volts 750 | volts 900 | volts 1050 |
|---|---|---|---|---|---|---|---|
| 1m ... | 22·0 | unsteady 74 | unsteady 85 | steady 84·5 | steady 100·0 | unsteady 118·2 | unsteady 143 |
| 2m ... | 21·6 | 54 | 71 | 80·5 | 94·5 | 118·0 | 139 |
| | 2960~ | 1730~ | 2280~ | 3050~ | 3230~ | 3260~ | 3140~ |

| | volts 1200 | volts 1050 | volts 900 | volts 750 | volts 600 | volts 450 | volts 300 | volts 150 |
|---|---|---|---|---|---|---|---|---|
| 1m ... | unsteady 167 | 154 | 125 | 96·5 | 70·5 | 52·5 | 34·0 | 16·6 |
| 2m ... | 193 | 152 | 123 | 96·0 | 67·0 | 44·2 | 27·5 | 14·6 |
| | 3070~ | 2920~ | 3080~ | 3350~ | 3660~ | 3690~ | 3760~ | 3920~ |

24th April, 1894. Temp. =63° F.

TABLE VIII.—Gutta-percha sheet ($G_2$).
(Volts *diminishing*.)

| | volts 1200 | volts 1050 | volts 900 | volts 750 | volts 600 | volts 450 | volts 300 | volts 150 |
|---|---|---|---|---|---|---|---|---|
| 1m ... | 231 | 143 | 99 | 68 | 50·0 | 37·6 | 25·8 | 13·0 |
| 2m ... | 187 | 131 | 94 | 65 | 48·7 | 35·6 | 24·0 | 12·3 |
| | 1620^ | 2290^ | 2830^ | 3430^ | 3720^ | 3700^ | 357 | 3550^ |

| | volts 300 | volts 450 | volts 600 | volts 750 | volts 900 | volts 1050 | volts 1200 |
|---|---|---|---|---|---|---|---|
| 1m ... | 25·6 | 37·4 | 47·0 | 58 | 73 | 91 | 109 |
| 2m ... | 23·8 | 34·6 | 44·5 | 58 | 75 | 92 | 117 |
| | 3600^ | 3720^ | 3970^ | 4020^ | 3780^ | 3600^ | 3430^ |

25th April, 1894. Temp. =62° F.

The small opaque white spots, observed within the celluloid under the microscope, led to some further experiments to investigate the effect of isolated foreign particles within the substance and upon the surface of dielectrics. Coarse brass filings were scattered as thickly as possible over one face of a warmed strip of gutta-percha, 16 inches long, 2 inches wide, and $\frac{1}{4}$ inch thick. The insulation of such a strip is not exactly what might be expected; when tested even with 750 volts its resistance was practically infinite, and was certainly greater than 600,000 megohms. A charged gold-leaf electroscope could not be discharged with such a strip in this condition. If, however, a wet cloth was passed once over the non-metallic face of the strip, or if it was simply breathed upon, the insulation fell to 5000 megohms, and the strip now easily discharged the electroscope. A round rod of gutta-percha can be warmed and rolled in a heap of brass filings so as to appear almost like a brass rod, and such a rod does not discharge the electroscope. This would be an instructive experiment for schools and instrument-makers.

### "*Sensitive*" *Dielectrics.*

The next experiments were made with rods formed of a mixture of gutta-percha and brass filings melted together in various proportions. The length of these rods was about 20 inches, and their diameter $\frac{3}{4}$ of an inch. Contact was made with the ends for about $1\frac{1}{2}$ inch by tin-foil which was bound round with wire. It is found that, for small proportions of brass filings, the resistance between the ends of these rods is exceedingly high, and this high resistance is maintained until about 2 parts, by weight, of brass are mixed with one part, by weight, of gutta-percha. Here a "critical" point of proportionality between the two substances occurs, *under* which the rods have a very low resistance, of something like one ohm; and *above* which the resistance is exceedingly high, and can only be measured in megohms. Several rods were made at or near this "critical" point, and in no case could a medium resistance of, say, a few hundred ohms be attained. All the rods were either of very high or very low resistance.

The method of making them is to warm a sheet of gutta-percha upon a hot plate, using French chalk to prevent sticking. The filings are sprinkled in as soon as the sheet becomes soft. The whole is then made up into a pudding, which is again flattened out into a sheet; this is repeated until a good mixture is arrived at. The compound is then rolled into rods.

Table IX. gives the proportion by weight of these rods and the corresponding resistance. When rods made up in this way are submitted to the action of oscillating discharges, they behave in a similar manner to the "impulsion" cells of Prof. Minchin and the tubes of M. Branly. If, for instance, one of the low-resistance rods of, say, four parts by weight of gutta-percha to nine of brass filings is connected to one arm of a Wheatstone's bridge and balanced, an oscillatory discharge made anywhere near it will, in nearly all cases, produce a considerable diminution of resistance—in some cases amounting to more than 10 per cent., and, in one experiment, to as much as 45 per cent. This charge remains until restored to the former condition of things by a slight mechanical tap. I have repeated this experiment upon seven different rods,

TABLE IX.

| No. of Rod. | Proportion by weight $\frac{\text{G.P.}}{\text{Brass}}$ | Approximate Resistance. |
|---|---|---|
| 1 ..... | $\frac{1}{2}$ | ·2 ohm. |
| 2 ..... | ? | ·07 „ |
| 3 ..... | $\frac{1}{3}$ | ·11 „ |
| 4 ..... | $\frac{1}{1}$ | $\infty$. |
| 5 ..... | $\frac{2}{1}$ | $\infty$. |
| 6 ..... | $\frac{2}{3}$ | 283,000 megohms. |
| 7 ..... | $\frac{4}{7}$ | 173,000 „ |
| 8 ..... | $\frac{1}{2}$ | $\infty$. |
| 9 ..... | $\frac{1}{2}$ | 770 megohms. |
| 10 ..... | $\frac{1}{3}$ | ·37 ohm. |
| 11 ..... | $\frac{2}{5}$ | 1·68 „ |
| 12 ..... | $\frac{1}{2}$ | 19 ohms. |
| 13 ..... | $\frac{4}{9}$ | 3·9 „ |
| 14 ..... | $\frac{4}{11}$ | ·48 ohm. |
| 15 ..... | .... | 1·5 megohm. |

and have, in each case, obtained a diminution when the discharge-spark passed at the oscillator. The small-resistance rods of Table IX. were all sensitive to these electromagnetic oscillations. The high-resistance rods do not come within the range of measurement of the usual form of Wheatstone's bridge; the ordinary insulation-test was therefore applied, using a battery of 400 Leclanché cells. In this way resistances up to 600,000 megohms could be measured. A rod composed of 4 parts, by weight, of gutta-percha, to 7 parts of brass filings had practically infinite resistance. Another, having 2 parts, by weight, of gutta-percha to 3 of brass, had 100,000 megohms. A third, made up in the ratio of 4 parts gutta-percha to 7 of brass, was of infinite resistance. Four rods were made in the proportion 1 gutta-percha to 2 of brass,

which is near the critical ratio of conductor to insulator; their resistances were, respectively, $\infty$, 40 megohms, and 12 ohms. The ·17-ohm rod exhibited a decided, but not very great diminution of resistance under the influence of the oscillator. Apparently, the high-resistance rods are unaffected by the discharges. The 40-megohm rod was not of very constant resistance, the spot moved up and down the scale; the spark had therefore to be passed at moments when the spot halted,—the result was not very satisfactory. At one time it was thought actually to *increase* the resistance of this rod. The 12-ohm rod was especially interesting from its extreme sensitiveness; in one condition it had a resistance of 19 ohms, the sudden passage of a spark at the oscillator reduced this by 45 per cent. The rod was generally unstable. The 40-megohm rod seemed the one most nearly corresponding, in its galvanometer-readings, with a faulty cable; the readings being erratic. Its resistance has, at times, been as high as 770 megohms. This rod is probably unstable in some opposite direction to the 12-ohm rod; they were both made in the same proportions and in the same manner. In Table IX. they appear as No. 9 and No. 12 respectively.

*Alternating Voltages.*

Tests were now made upon specimens submitted to alternating currents, and I have to thank Mr. George Bousfield for assisting me in this part of the experiments. I took the strip sprinkled with filings, and two rods; these were first tested for insulation in the ordinary way, with the following results:—

| Dielectric. | Resistance. |
|---|---|
| Strip | $= \infty$. |
| No. 6 | = 283,000 megohms. |
| No. 9 | = 47·2 megohms. |

The strip began to break down under the action of the alternating current at 900 volts; at 3000 volts it was emitting small local arcs, some crimson, others violet. After the application for some time of this high voltage the number and brilliancy of the arcs diminished,—the insulation had apparently improved. At 5500 volts there were bright discharges similar to the first. These were not of the nature of long sparks, but of small local arcs.

Rod No. 6 gave way at 6500 volts and exhibited the same apparent improvement in insulation. The arcs shot out in miniature flames, like very small blowpipe blasts; locally, as in the case of the strip.

With rod No. 9 sparking commenced at 1500 volts, having the appearance of small beads of crimson and violet light burning themselves out at fixed points. When these specimens had become cool their insulation was again tested.

| Dielectric. | Resistance. |
|---|---|
| Strip | $= \infty$. |
| No. 6 | = 70,750 megohms. |
| No. 9 | = 2020 megohms. |

The strip thus appears to have recovered entirely. No. 6 has fallen to a quarter of its first value, and No. 9 has greatly improved, under this trying ordeal.

Rod No. 15 was compounded of iron filings, Sr, &c., with a view to obtaining a brilliant discharge. The salts brought the insulation down rather low; there was a great deal of heat generated, and little else. Such a rod should probably be made simply of metallic powders intermixed with the dielectric.

## Discussion.

Mr. Enright asked questions as to the electrification of gutta-percha, and the bridge-connexions in the resistance tests of the semi-conducting rods respectively.

Mr. Charles Bright said the curious phenomenon, in Mr. Appleyard's experiments, of the dielectric resistance of gutta-percha strip remaining much the same when brass filings were pressed on to its surface, is, of course, most interesting. These filings, as I understand, had no appreciable effect electrically until a certain quantity were incorporated, when the resistance suddenly broke down and, in fact, soon gave good conduction. The explanation of this fact is presumably that as long as the metal filings are not sufficiently closely packed to be touching one another, they take no material part in the conduction of electricity through the gutta-percha, but when once they touch one another sufficiently closely, the conduction (or resistance) of the gutta-percha sheet becomes practically that of the brass.

## XVII. *Note on the Behaviour of certain Bodies in presence of Electromagnetic Oscillations.* *By* Prof. G. M. Minchin, *M.A.**

The question of the employment of impulsion-cells, metallic films, and bodies of similar behaviour, for detecting the nodes &c. of electromagnetic vibrations, has frequently been raised; and the reading of Mr. Appleyard's paper on rods formed of a mixture of gutta-percha and metallic filings offers an opportunity for a few remarks on the subject.

So far as experiment has gone hitherto, it does not seem possible to use these bodies for detecting nodes; and the reason is simply this—that the physical states of the bodies in question are too variable to admit of the observation of any constant *régime*.

I have lately made a few observations on films and metallic surfaces formed by imbedding fine metallic powders in thin layers of gelatine, shellac, and sealing-wax spread on plates of glass, in continuation of the work described and experimentally illustrated at a previous meeting of the Physical Society; and the results are, briefly, as follows:—If we put in the circuit of a battery and a galvanometer a surface formed by fine metallic powder imbedded in a layer of sealing-wax, we find that this surface (although, to the eye, a continuous surface of metal) is a non-conductor. Indeed, if the electrodes connected with this surface are also connected with an electrometer, we find that this surface has an *infinite* resistance. Now if feeble electromagnetic oscillations are produced in the neighbourhood of the non-conducting surface, it will refuse to respond and remain a non-conductor. Let the field round the surface be greatly increased, or let one of the electrodes be actually touched by a charged body: then the surface becomes a conductor. Let its conductivity be now destroyed (by breaking the contact of the surface with the electrode, for example, as described in my previous paper), and it will be found after this to respond very

* Read as part of the discussion on Mr. Appleyard's paper on Dielectrics, May 11, 1891.

easily to the actions which previously produced no effect upon it. In other words, *once we have succeeded in driving a current through the metallic-powder surface, it responds to very feeble electromagnetic impulses, whereas it previously failed to respond to strong impulses.*

When the contact of the surface with the electrode is broken and then almost instantly re-made, the behaviour of the surface depends on certain things. Firstly, if the metal powder forming the surface is embedded in gelatine which retains some plasticity, the breaking of the contact is fatal to the conductivity of the surface : the surface rapidly reverts to the non-conducting state. Secondly, if the substratum of the metallic powder is a hard substance like sealing-wax, and if the electromagnetic impulses received by it have been strong, the surface will remain a conductor for a long time—possibly for 24 hours or more. But if the impulses to which it has been subjected have been small, and the conductivity consequently small, the surface rapidly reverts to the non-conducting state, less than a minute's breaking of contact sufficing to re-establish insulation.

Again, surfaces with a hard-set substratum (like sealing-wax) are scarcely, if at all, sensitive to mechanical impulses.

A series of experiments made with a particular surface gave this as an almost invariable result—if the surface is in the non-conducting state, and a feeble electromagnetic field is produced round it, it becomes a conductor ; but if, while it is conducting, a strong field be produced round it, its conductivity is destroyed. I have no doubt that a law of this kind holds for all such bodies ; the nature of the change produced in them depends either on the amplitudes or on the frequencies of the incident impulses ; but, in order to verify it, we should be able to deal with a film which from a definite state of non-conductiveness changes always to a definite state of conductivity ; and this has been, so far, impossible.

It may be well to give a numerical illustration of the change of resistance produced in a film. Thus, when the electrodes touching a tin-powder surface were two platinum wires the extremities of which were rounded in an oxy-hydrogen flame, and the length of the film in a right line

between them was about 1 centim., the resistance of the surface varied from $\infty$ to about 130 ohms. This resistance was measured by connecting the poles of a quadrant electrometer with the above platinum electrodes, while the current of two Leclanché cells was passing through the galvanometer and metallic surface, and reading the difference of potential indicated by the electrometer.

Of course this assumes that no E.M.F. is set up in the film by the electric impulse which rendered it a conductor—an assumption the truth of which was verified by using a key which suddenly threw the battery out of circuit and inserted the electrometer instead. Not the slightest E.M.F. in the film could be detected.

I must, however, repeat what I have previously stated concerning the nature of an impulsion-cell—viz., that, while in the case of films and M. Branly's tubes of metallic filings the whole phenomenon relates merely to changes of resistance, this is not the case for an impulsion-cell. The current of a single Minotto can pass through the impulsion-cell both in its state of insensitiveness to light and in its state of sensitiveness.

It may be natural to conjecture that iron powder might present some striking difference from those of other metals; but, forming surfaces with the magnetic oxide of iron, I was not able to detect any special characteristic of such surfaces.

The behaviour of all these bodies in very weak fields and in very strong ones is a matter which requires working out.

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## XVIII. *The Passage of Hydrogen through a Palladium Septum, and the Pressure which it produces.* *By* William Ramsay, *F.R.S.*

It has been frequently cited as an argument in favour of attributing the osmotic pressure exercised by a substance in dilute solution on the walls of a vessel permeable to the solvent but not to the dissolved substance, that if a vessel were constructed of palladium, which, as Graham's researches showed, is permeable to hydrogen, but not to many other

* Read May 25, 1894.

gases, such a vessel would be subjected on its interior walls to a high pressure if it were filled with an indifferent gas and exposed on its exterior to an atmosphere of hydrogen. The gas confined in the vessel, not being able to escape, would exert the pressure at which it was allowed to enter ; while the interior of the vessel would be a vacuum to hydrogen ; and as its walls are permeable to hydrogen, pressure should rise by passage of hydrogen into the interior, until the pressure of the hydrogen on the interior walls became equal to that on the exterior walls. The effect of this would be to superadd the pressure of the hydrogen to that of the gas originally contained in the vessel ; and if it be supposed that the vessel was originally filled at atmospheric pressure, the entry of hydrogen should increase that pressure by another atmosphere, providing the hydrogen surrounding the exterior walls of the vessel be at atmospheric pressure.

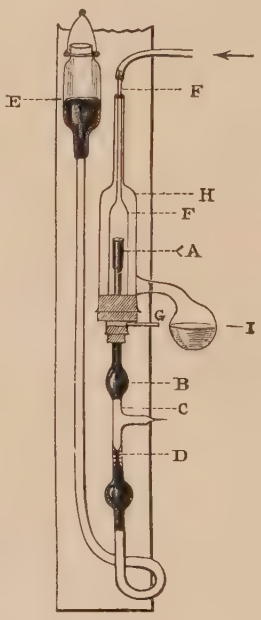
It has been suggested that when pressure is raised by the passage of water into the interior of a cell with semipermeable walls containing a solution, the rise of pressure is due, not to the pressure exercised by the molecules of the dissolved substance, but to that produced by the entering water. Gases present us with an exact analogy. It is idle to inquire what causes the rise of pressure in the interior of such a palladium "cell." The total pressure is due to the hydrogen and to the gas with which the cell was originally filled ; the original pressure has undoubtedly been increased by the entry of hydrogen. But a portion of the pressure—and the effective portion, from the point of view of osmotic pressure—is due to the original gas, whether nitrogen, carbon dioxide, or any gas whatever to which the cell-walls are impervious, and which is not chemically attacked by hydrogen. It is therefore quite correct to ascribe osmotic pressure to the dissolved substance, although it is apparently produced by entry of solvent.

The experiments to be described were made with the object of submitting this entry of hydrogen through the walls of a palladium cell to quantitative study. After considerable progress had been made, a paper by A. Biltz (*Zeitschr. f. phys. Chem.* ix. p. 152) was published, describing lecture-experiments devised to show the ordinary diffusion of gases without a septum, diffusion with a leaky septum of porous

earthenware, and also diffusion with a semipermeable septum, permitting the passage of hydrogen, but hindering the passage of other gases. Biltz employed for the last-mentioned purpose an iron tube, and made a few rough quantitative measurements ; but he does not appear to have continued any experiment long enough to obtain a maximum pressure, nor was his apparatus designed with the object of quantitative measurement, but only for the purpose of class demonstration.

*Description of Apparatus.*

The apparatus which was employed is represented in the accompanying woodcut.




AB is a tube of platinum, the top portion of which, at A, is of palladium and closed at its upper end. At B the platinum tube is sealed or cemented on to a glass tube C, with a lateral branch, represented in the figure as drawn off and closed. Somewhat lower down, the tube is sealed to a capillary D, on which graduations are etched. The tube then widens to a bulb, and is finally connected by thick flexible tubing to a reservoir of mercury E.

The palladium tube is surrounded by a glass tube F, also provided with a lateral exit at G, and fitting tightly into a jacket H, which may be heated by boiling the liquid in the bulb I. A gas, passed in at F, would thus surround the palladium tube and escape at G ; or if heavier than air, if introduced at G it would escape at F. The palladium cell could be heated to any desired temperature by choosing an appropriate jacketing vapour. The whole apparatus stood in front of a glass mirror-scale, on which the level of the

mercury at D and E could be read off. It was possible to read to one tenth of a millimetre, but such accuracy of reading was generally unnecessary.

*Description of an Experiment.*

A clip was placed on the india-rubber tube joining D and E, and the side-tube C, which at this time was open, was connected with a reservoir of some gas, *e. g.* of nitrogen, by means of a three-way tap. The palladium tube was pumped empty, and then filled with dry nitrogen ; the operation was repeated ten times, so as to ensure absence of air. The nitrogen was finally allowed to enter the apparatus under slight pressure, and the side-tube C was sealed. The liquid in I was then boiled so as to jacket the tubes F and A, and the clip on the india-rubber tube was opened. When the temperature had become constant, the reservoir of mercury E was brought approximately to a level with a mark on the capillary tube D, and the capillary tube at C was broken. Gas then escaped through C until the pressure in the tube A became equal to that of the atmosphere. The capillary point was again sealed. An accurate reading was then taken, the mercury reservoir being placed so that an exact volume of gas was contained in the palladium cell under a known pressure.

Hydrogen carefully purified by washing with potassium permanganate, silver nitrate, and caustic potash, and dried by passage through sulphuric acid and over phosphorus pentoxide, was then passed in through the tube F, escaping at G. Pressure rapidly rose in the interior of the apparatus, and was measured by raising the mercury reservoir. When it had attained its maximum a reading was taken, the position of the mercury in the capillary stem being so adjusted that the capacity of the cell was accurately the same as at the commencement of the experiments. The difference between the initial and final pressure is due to entry of hydrogen.

The success of such experiments depends on the condition of the palladium. After having been used once or twice the interior of the palladium tube became coated with mercury, even although the level of mercury (which was cold) lay far below the palladium top. It appears that palladium absorbs

mercury-vapour with avidity, thus rendering the palladium cell a partial vacuum to mercury-vapour. Vapour rises from the cold mercury to restore pressure, and is again absorbed. It was therefore necessary to heat the palladium tube after each experiment in order to expel mercury. This had the effect of oxidizing the palladium and of covering it with a brownish-black film. To remove the oxide, the tube was made the negative pole of a battery, and dilute sulphuric acid was electrolysed, both on the inside and outside of the palladium tube. It was then dried at a low temperature ; the external surface was polished with a little dry emery ; the tube was cemented into its place, and was ready for a fresh experiment. Without such precautions the passage of hydrogen is very slow and incomplete. It should be mentioned that before commencing an experiment it was necessary to jacket the palladium tube at 220° and to pass a current of air over it for some time. In this way the combined hydrogen was removed; hydrogen escaped from the exterior of the tube and was replaced by air or some other gas in the interior.

*Account of Experiments.*

The experiments admit of classification under five heads:—

1. Experiments with the tube filled with air.
2. Experiments with the tube filled with nitrogen.
3. Experiments in which the hydrogen passed over the exterior of the tube was diluted with nitrogen or other gases, when it exercised only a partial pressure on the exterior walls of the tube.
4. Experiments in which the palladium tube was filled with other gases.
5. Experiments with a nickel tube and carbon monoxide.

*Experiment* 1.—The tube was filled with air and jacketed with bromonaphthalene, boiling at about 280°. The barometric pressure during the experiment was constant at 743·1 millim. On passing hydrogen for three hours the pressure in the palladium cell had become constant ; the rise of pressure was 573 millim.

Water appeared on the surface of the mercury in the capillary tube, showing that the hydrogen had combined with the oxygen of the air. The rise of pressure measured should

therefore have been that of the nitrogen remaining in the cell, viz 585 millim.

It may be concluded, then, that hydrogen combines with oxygen in presence of palladium at 280°, and that the residual nitrogen exerts nearly its partial pressure; or, as will be afterwards shown to be a more correct statement, the nitrogen exerts its full partial pressure, and the hydrogen in the interior exerts a large fraction of the pressure of the external hydrogen.

*Experiment* 2.—The tube was filled with pure dry nitrogen, and exposed to hydrogen, as before, at the same temperature. The pressure, after it had become fairly steady, was 703·2 millim. in excess of that of the atmosphere (748·1 millim.). The hydrogen was next removed by passing a current of air over the exterior of the tube, and the pressure was again raised by a current of hydrogen. After about three-quarters of an hour the pressure was 699·8 millim. in excess of that of the atmosphere, a quarter of an hour later it was 721·1 millim., and in another quarter of an hour it had risen to 733·0 millim. It appeared then to be stationary. The barometric pressure was still 748·1 millim.; it therefore appears that the pressures of the hydrogen on the exterior and interior of the palladium tube were nearly equal.

It was noticed during these experiments that when the gas was changed the pressure invariably fell a little on admitting hydrogen and rose a little on admitting oxygen; the direction of the pressure then changed, and the usual rise with hydrogen and fall with air occurred. I think that this is to be attributed to the fact that the palladium vessel increases its capacity suddenly on exposure to hydrogen, and decreases it on exposure to air after having been exposed to hydrogen. But the total change of volume is a very minute one; it is noticeable only by the rise or fall of the mercury in the capillary tube to the amount of one or two millimetres; and the total change of volume is certainly less than 0·1 per cent. of the capacity of the vessel.

*Experiments* 3, 4, *and* 5.—The next three experiments gave readings much lower than those previously obtained. The barometric reading was 748·6 millim. The rise in experiment 3 was 650·3 millim.; in experiment 4, 654·2 millim.; and in experiment 5, 657·8 millim.

This led me to suspect that the palladium tube had undergone alteration. It was therefore disconnected and cleaned as before described. It was finally filled with nitrogen.

*Experiments* 6, 7, 8, 9, *and* 10.—The barometric pressure was 770·2 millim. The final pressure in experiment 6 was 698·5; in 7, 692·1; in 8, the barometric pressure being 768·8 millim., the final pressure was 686·4 millim. In experiment 9, with a barometer-reading of 762·2 millim., the reading was 692·4 millim.; and in 10, the barometer-reading being 759·2, the pressure was 688·4 millim.

To summarize these results it is necessary to compare the pressure of the internal hydrogen with that of the external hydrogen. The following table gives their ratios :—

| Experiment. | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Ratio . . . . | 0·9400 | 0·9798 | 0·8687 | 0·8739 | 0·8780 |

| Experiment. | (6) | (7) | (8) | (9) | (10) |
|---|---|---|---|---|---|
| Ratio . . . . | 0·9069 | 0·8986 | 0·8928 | 0·9084 | 0·9067 |

These results do not exhibit any great degree of constancy, but I am sure that their difference depends largely, if not wholly, on the state of the surface of the palladium. The mean result is 0·9053, a number closely approximating to the last five determinations. This would lead to the conclusion that the pressure of the internal hydrogen rises to rather more than $\frac{9}{10}$ of the pressure of the external hydrogen at 280°.

*Experiment* 11.—The temperature was now kept at the boiling-point of quinoline (about 237°). The passage of hydrogen through palladium is so slow at this temperature that patience failed me to make more than one determination. It was begun on May 4th. On May 10th pressure was still rising, but very slowly. On May 11th it had reached 501·7 millim.; on the 13th it was 525·2 millim., and on the 14th 531·2 millim. Taking the figure actually read, the fractional pressure (barometer = 766·3 millim.) was 0·6932. Judging from this experiment, the pressure would appear to depend on the temperature of the palladium and of the hydrogen. Still, it is possible that had the experiment been carried on sufficiently far, the pressure might have risen much higher.

*Experiment* 12.—The next set of experiments was made at a higher temperature—that of the boiling-point of dibenzylketone (335°). The pressure registered at a barometric height of 758·7 millim. was 681·6 millim. The ratio is 0·8984, practically identical with that obtained at the boiling-point of bromonaphthalene.

*Experiments* 13, 14, *and* 15.—The hydrogen in these experiments was mixed with 50 per cent. of nitrogen, so that the exterior of the palladium tube was exposed to a partial pressure of hydrogen. The first of this set gave a pressure of hydrogen of 367·9 millim., the barometer standing at 770·9 millim. ; the second, 352·9 millim., barometer at 771·8 millim. ; and the third 362·7 millim. at the same pressure.

*Experiment* 16 was made with a mixture of one volume of hydrogen to three of nitrogen ; the read pressure was 176·7 millim., the barometric height being 756·5 millim.

The ratios are :—

| Experiment. | 13 | 14 | 15 | |
|---|---|---|---|---|
| Ratio . . . . | 0·4771 | 0·4573 | 0·4700. | Mean 0·4681. |

Experiment 16 : Ratio 0·2336.

Multiplying the first mean ratio by 2, and the second by 4, the products are comparable with that from pure hydrogen. The figures are :—

| | |
|---|---|
| Pure hydrogen . . . . . | 0·9053 |
| Hydrogen + 50 p. c. nitrogen . . . | 0·9362 |
| Hydrogen + 75 p. c. nitrogen . . . | 0·9544 |

The pressure, as might have been anticipated, is proportional to the partial pressure of the external hydrogen.

It is obviously possible to test the percentage of hydrogen in coal-gas by this means, provided the other constituents of coal-gas are unable to pass through palladium. An experiment with marsh-gas showed that it is not capable of permeating palladium ; and the vapour of ether is also unable to pass.

*Experiments* 17 *and* 18.—At 280° the pressures with a sample of London coal-gas were 364·4 millim., at a barometric pressure of 760·4 millim. ; and 361·8 millim. at a barometric pressure of 761·5 millim. The ratios are 0·4792 and 0·4751 respectively. Supposing the highest attainable ratio to be

0·9053, as deduced from the ten experiments with pure hydrogen, the percentage of hydrogen is easily found by the ratios $(0{\cdot}4792 \times 100)/0\ 9053$, and $(0{\cdot}4751 \times 100)/0{\cdot}9053$. The numbers are 52·94 and 52·49 per cent. respectively. It would be possible thus to have a continuous register of the percentage amount of hydrogen in coal-gas, provided the palladium did not alter its state. As it is, I am afraid that the apparatus will not retain its activity for a sufficiently long time. It should also be remarked that it is necessary to wash the coal-gas with a solution of potassium permanganate, in order to free it from sulphur compounds. If this precaution is not taken, the palladium becomes coated with a layer of sulphide, and it ceases to be permeable to hydrogen.

Experiments were next made in which the palladium tube contained various gases.

*Experiment* 19.—The tube contained carbon dioxide. On exposing it to hydrogen at 280° the pressure rose with great rapidity—much more rapidly than had previously been observed. The rise ceased at 735 millim., the barometric pressure being 764·0. The quotient is 0·9621, a higher number than any yet obtained.

*Experiment* 20.—Carbon monoxide was in the interior; the pressure rose rapidly on admission of hydrogen to 734·5 millim., the barometer reading 769·5. The quotient is 0·9545, also a very high number. In both of these experiments the fall on passing air over the exterior of the tube was much slower than the rise with hydrogen. The end point was difficult to note, for the last change of pressure was very slow. It may be that the exterior surface of the palladium being exposed to hydrogen alone, little difficulty was experienced in molecules entering; but that on reversing the action, the contact of hydrogen with the interior walls was interfered with by the indifferent gas present. The same phenomenon had previously been noticed, but in a minor degree. It is noteworthy that no trace of water was formed in either case. Hydrogenized palladium is without action on carbon monoxide or dioxide at 280°.

*Experiment* 21.—The tube was filled with cyanogen. The total pressure was 741 millim., the barometer standing at 764·5 millim. The quotient is 0·9693, a very high number.

# PHYSICAL SOCIETY OF LONDON.

# ABSTRACTS OF PHYSICAL PAPERS

## FROM FOREIGN SOURCES.

JANUARY 1895.

### GENERAL PHYSICS.

1. *Pure Water.* **F. Kohlrausch** and **A. Heydweiller.** (Wied. Ann. 53. pp. 209–235, 1894.)—The conductivity of water in contact with the air never sinks below $0{\cdot}7\times10^{-10}$. If distilled *in vacuo*, the minimum is $0{\cdot}25\times10^{-10}$, always at 18° C. Using one of the two glasses employed ten years ago, and kept full of water since, F. Kohlrausch and Heydweiller observed the minimum $0{\cdot}04\times10^{-10}$. The paper describes the recent researches, and contains several novel points. Certain glasses gradually become insoluble in water. Remelted ice has a lower conductivity, but an already pure water can hardly be improved in this way. A natural ice-water gave only $0{\cdot}2\times10^{-10}$; the conductivity of the original water could hardly have been less than 300. There is no discontinuity at 0° or 4°. The determinations were made with a sort of Thomson mirror-galvanometer, 16 chromic-acid cells, and current-impulses of less than 0·1 second, whose directions were occasionally changed. No polarisation was observed, nor did the resistance vary under pressures from 4 to 120 volts, so that Ohm's law remains valid for pure water. Quite unexpected was the observation that longer current-impulses increased the conductivity by as much as 100 per cent. There was a slow return to normal, accelerated by agitation. Reversal of the current first created an increase, soon followed by a decrease. The cause of this peculiarity is probably to be found in decompositions starting from the electrodes, as in Lehmann's experiments. The conductivity of pure water is remarkably influenced by the temperature, the temperature-coefficient being at 50° C. six times as great as that of dilute solutions.

This should be so according to the dissociation theory, and was predicted by Arrhenius. With the help of van't Hoff's formula, the authors eliminate the influences of the impurities, and arrive at the value $0{\cdot}036 \times 10^{-10}$ for the conductivity of pure water. The impurities of this best water would not amount to more than a few thousandths of a milligramme in one litre. At 18°, one cubic metre of water would contain 0·8 mg. of dissociated hydrogen, at 100°, 0·85 mg.; enough in the authors' opinion to assume milliards of atoms in one cubic millimetre at wave-lengths' distance apart—hence the validity of Ohm's law. A postscriptum mentions that newer researches of Ostwald, Arrhenius, Wijs, lead to dissociation values of the same order. H. B.

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2. *Change of Volume at Melting.* **M. Toepler.** (Wied. Ann. 53. pp. 343–378, 1894.)—Toepler pours the fused substance into a strong test-tube under oil, seals a capillary tube into the narrow neck, empties while heating and cooling until all air is expelled, and surrounds the dilatometer with a glass cylinder 5 cm. in width. The vertical rise in the expansion curve (often a straight line) from or to the melting-point gives the change of volume, which he expresses in c. c. per gramme of substance, calling this coefficient $k$. When the rate of increase of expansion is not constant, as in the case of potassium, the vertical rise is difficult to trace. The described dilatometer was used for Na, K, Rb, Sn, Bi, Tl, and for S and Se, whose allotropic modifications were more carefully studied. In general, Toepler does not aim at extreme accuracy. The oil indicator was not applied for I, Br, Zn, Pb, Te. Some metals, Sb, Cd, Al, were melted in an iron block with a **U**-shaped bore-hole fitted with a tubular neck. The liquid metal was allowed to rise a little above the margin; the excess was then scraped off, and the depression afterwards determined. The data suffice to demonstrate a marked similarity between the atomic volume-curves, and the curves combining this coefficient and the atomic weights. H. B.

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3. *Effect of External Pressure on Saturation-Pressure of Vapour.* **N. Schiller.** (Wied. Ann. 53. pp. 396–400, 1894.)—This explains a method of showing the influence of a curved liquid surface or of an electrostatic field on the saturation-pressure of a vapour. A liquid and its saturated vapour, enclosed between two moveable pistons of a vertical cylinder, would be in equilibrium under an inward pressure on both pistons equal to that of the vapour if the separating surface is flat and weight is neglected. If the surface is curved and consequently an inward pressure $q$ is produced on the liquid at the surface, equilibrium will be maintained by additional inward pressures $X_1$, $X_2$ on the lower and upper pistons such that

$$X_1\delta x_1 + X_2\delta x_2 + q\delta x \not> 0,$$

where each displacement is positive in the direction of the corresponding pressure, and

$$(\delta x+\delta x_1)/\sigma=(\delta x-\delta x_2)/s,$$

or

$$s\delta x_1+\sigma\delta x_2+(s-\sigma)\delta x=0,$$

where $s$, $\sigma$ are the specific volumes of the vapour and liquid:

whence $$X_1=qs/(s-\sigma),\ X_2=q\sigma/(s-\sigma).$$

Thus the vapour-pressure over a curved surface is greater than that over a flat one by $q\sigma/(s-\sigma)$, and $q=\pm T(1/r+1/r')$, where the upper or lower sign is to be taken according as the curvature is convex upwards or downwards. With an electrostatic field of strength R at a point of the surface where the potential is $\phi$,

$$q=(\partial\phi/\partial n)^2(K'-K)^2/8\pi K'-R^2\{(K'-K)/8\pi+\theta/2\}.$$

Further, if there is mixed with the vapour a gas producing a partial pressure $p$, the vapour-pressure must thereby be increased by $p\sigma/(s-\sigma)$. R. E. B.

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4. *Repeated Fusion of Lead-Tin Alloys.* **B. Wiesengrund.** (Wied. Ann. 52. pp. 777–792, 1894.)—Wiesengrund used a crucible of thin sheet-iron, 50 mm. high, 25 mm. wide below, 45 mm. above, covered with a lid, and suspended in a double shell. During cooling the crucible was charged with dry hydrogen. The specific gravities of the twelve alloys, all of atomic proportions varying between $Pb_{12}Sn$ and $PbSn_{12}$, were all found lower than calculated; $PbSn_3$, which seems to be a chemical compound, differed most. Three series of observations were made:—I. Six alloys were refused 10 times without stirring. II. All twelve were refused 24 times, and agitated after each third time. III. The process of II. was interrupted for weeks and months. The alloy $PbSn_3$ alone had a constant melting-point, at which it solidified again, 183° C. The melting-points of the others rose gradually (by about 1° C.), whilst the solidification-points approached 183°. The more tin the mixture contains, the higher lies the point at which the thermometer remains stationary for some time. This temperature did not vary by more than 1° for each particular mixture. The author draws a parallel between alloys and solutions, regarding the Sn as solvent. H. B.

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5. *Fracture under Stress and Strain.* **W. Voigt.** (Wied. Ann. 53. pp. 43–56, 1894.)—The question has been raised whether fracture is determined by a limiting strain, or limiting stress; to settle this, the author made experiments on the tenacity of rock-salt prisms when subjected to a longitudinal tension $-X_x$ and a simultaneous lateral pressure $Y_y$ and $Z_z$. The specimens, which were moderately uniform, were stretched by a spring, inside a

vessel which could be filled with carbon dioxide at 60 atmos., to produce the lateral pressure. Results:—

$$-X_x = 580 \text{ gms. per sq. mm. when } Y_y = Z_z = 0,$$
$$-X_x = 40 \quad \text{,,} \quad \text{,,} \quad Y_y = Z_z = 520.$$

So that the tension applied by the spring $= -X_x + Y_y$ is nearly the same in the two cases. It follows that neither a definite stress nor strain characterises the fracture. A positive conclusion was not arrived at, but the author suggests

$$-X_x + a(Y_y + Z_z)$$

as the criterion, where $a$ is a constant, in this case nearly $\frac{1}{2}$.

R. A. L.

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6. *An Automatic Mercurial Air-Pump.* **G. W. A. Kahlbaum.** (Wied. Ann. 53. pp. 199–209, 1894.) — The pump described requires the use of an auxiliary air-pump. The mercury, after having fallen, is sucked—mingled with columns of air—up a tube, falls into the longer arm of a sort of **U**-tube, and passes from the extremity of the shorter arm, through air-traps, into the air-pump proper. A drying-bottle containing phosphoric anhydride is interposed between the water-pump and the remainder of the apparatus. A vacuum under 0·000003 millim. has been obtained; appended are facts concerning the efficiency, maker, and price.

A. G.

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7. *Elasticity.* **W. Voigt.** (Wied. Ann. 52. pp. 536–555, 1894.)—A mathematical memoir, showing the results of assuming that the elastic potential includes, in addition to the usual terms involving the deformations in the second degree, others of the third degree.

R. A. L.

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8. *Vortex Motions in Air.* **G. Quincke.** (Wied. Ann. 52. pp. 607–608, 1894.)—Drops of oil made heavy by the addition of chloroform fall vertically in free water, but describe a sinuous path near the wall of the vessel, alternately approaching and receding from it. Two drops falling side by side will influence each other in the same way. These motions are produced by vortices in the water. Similar motions are exhibited more strikingly by soap-bubbles inflated with coal-gas and ascending in air. The plane midway between the two drops or bubbles is a plane of symmetry, and is not affected by the vortices.

E. E. F.

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9. *Freezing-Point and Osmotic Pressure.* **C. Dieterici.** (Wied. Ann. 52. pp. 263–274, 1894.)—The continuation of a discussion between the author and Arrhenius on the extent to which a proportionality exists between the lowering of the freezing-point of a solution and the osmotic pressure.

S. S.

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10. *Absorption of Hydrogen by Water and Aqueous Salt Solutions.* **P. Steiner.** (Wied. Ann. 52. pp. 275–299, 1894).—From Steiner's absorption-chamber, a glass vessel of 616·9 c. c. capacity, a capillary copper tube, 1·5 mm. wide, 2 m. long, wound in two turns of 15 cm. radius, leads over to a bulb and a graduated tube, of 80 c. c. capacity, connected with a mercury cistern. The capillary and the tube having been filled with dry hydrogen (from zinc), communication is established with the absorption-chamber, which is shaken whilst in a horizontal position with the cock half open. This shaking broke the platinum capillary first employed. There is no bubbling of the hydrogen through the liquid. The shaking is continued for about ten minutes, until there is no further rise of the mercury in the graduated tube, and the readings taken an hour afterwards at temperatures varying between 10° and 19° C. From these, Steiner deduces his coefficient, vol. of H/vol. of liquid, $\beta_{15}$, being forced to assume that the temperature-coefficients of the various solutions were the same. For water he found 0·01883, same as Winkler; Timofejew 0·01903, all at 15° C. The salts, LiCl, $KNO_3$, $\frac{1}{2}AlCl_3$, KCl, $NaNO_3$, $\frac{1}{2}CaCl_2$, NaCl, $\frac{1}{2}MgSO_4$, $\frac{1}{2}ZnSO_4$, $\frac{1}{2}Na_2SO_4$, $\frac{1}{2}K_2CO_3$, $\frac{1}{2}Na_2CO_3$, $C_{12}H_{22}O_{11}$, in saturated and dilute solutions, all gave remarkably regular and similar absorption-curves; the above order is for decreasing values, the nitrates and LiCl showing the least molecular depression. In their case the effect of acid and of base seems to be additive. The equivalent weights, not the molecular weights, appear to be decisive. Cane-sugar, the only non-electrolyte tested, occupies an isolated position; its curve crosses the others. Setschenow's absorption-coefficient for $CO_2$ gives similar curves. H. B.

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11. *Measurements of Vapour-Tension. First Notice.* **G. W. A. Kahlbaum.** (Zschr. phys. Chem. 13. pp. 14–55, 1894.)—The paper is an extract from a work with the same title published by Kahlbaum and Paul Schröter at Basel, in which full details are given of the apparatus and methods of observation. The author distinguishes two methods of determining vapour-tension—the dynamical and statical. The author's dynamical determinations of the vapour-tensions of formic, propionic, normal butyric, and iso-valerianic acids differed from Landolt's, who employed the statical method. A repetition of Landolt's measurements produced an agreement between the two methods, and showed that traces of water in Landolt's specimens were no doubt responsible for the differences. In general, water increases the vapour-tension when mixed with a fatty acid, and the effect of an equal quantity increases with the molecular weight; in the case of formic acid, the presence of water diminishes the vapour-tension. The preceding is followed by a section containing tables of the boiling-points under various pressures, and the vapour-tensions at various temperatures of a number of fatty acids, beginning with formic.

Mixtures, in known proportions, of formic acid and water, acetic acid and water, are next examined; and, finally, mixtures of certain acids. A. G.

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12. *Kinetic Interpretation of the Dissipation Function.* **L. Natanson.** (Zschr. phys. Chem. 13. pp. 437–444, 1894; Bull. Internat. de l'Acad. d. Sc. de Cracovie, 1893.)—Putting $u+\xi, \ldots$ for the components of velocity of a molecule, where $u, \ldots$ are the mean velocity-components of all the molecules in the volume $dV$, we have $K=\frac{1}{2}\int(u^2+\ldots)\rho dV$ for the molar, and $E=\frac{1}{2}\int(\overline{\xi^2}+\ldots)\rho dV$ for the molecular, kinetic energy of the medium; and putting $Q=(u+\xi)^2+\ldots$ in the general equation

$$\rho d\overline{Q}/dt+\partial(\rho\overline{\xi Q})/\partial x+\ldots=\rho(\delta\overline{Q}/\delta t+X\partial\overline{Q}/\partial u+\ldots)$$

and in the continuity-equations

$$\rho du/dt+\partial(\rho\overline{\xi^2})/\partial x+\partial(\rho\overline{\xi\eta})/\partial y+\partial(\rho\overline{\xi\zeta})/\partial z=\rho X, \text{ \&c.},$$

where Q is a function of the velocity-components of a molecule, $\rho X, \ldots$ is the external force at $x, y, z$, and $d$, $\delta$ denote total and collision-caused variations respectively, we obtain expressions which on integration over the containing volume give

$$\frac{\partial E}{\partial t}=\int(uX+\ldots)\rho dV-\frac{\partial K}{\partial t}=-\int(a\overline{\xi^2}+A\overline{\eta\zeta}+\ldots)\rho dV$$

$$=\int(F-p\theta)dV,$$

where

$$a\equiv\partial u/\partial x, \quad A\equiv\partial v/\partial z+\partial w/\partial y, \text{ \&c.}, \quad \theta\equiv a+b+c, \quad 3p\equiv\rho(\overline{\xi^2}+\ldots),$$

and

$$F\equiv a(p-\rho\overline{\xi^2})-A\rho\overline{\eta\zeta}+\ldots$$

Certain considerations seem to show that the sign of F depends on the character of the collisions; but with Poisson's theory

$$p-\rho\overline{\xi^2}=2\mu(a-\tfrac{1}{3}\theta), \quad \rho\overline{\eta\zeta}=-\mu A, \text{ \&c.},$$

so that F becomes Lord Rayleigh's dissipation-function

$$\mu(2a^2+A^2+\ldots-\tfrac{2}{3}\theta^2) \text{ or } \mu\{\tfrac{2}{3}(b-c)^2+A^2+\ldots\},$$

which is always positive. The transformation of molar into molecular energy is, therefore, an irreversible process, the term $p\theta$ not influencing this result as, varying in sign with $\theta$, it corresponds to a reversible process. The internal energy of the molecules has been neglected in the above; it adds a term $\rho d\overline{h}/dt$ to the equation to be integrated. R. E. B.

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13. *Improved Balance.* **B. Pensky.** (Zschr. Instrumk. 14. p. 325, 1894.)—In 1892, Messrs. Nementz of Vienna devised a contrivance for putting the smaller weights on a chemical balance without opening the case. They have now done the same for the

larger weights. The weights, 50 gr. and $4 \times 10$ gr., are ring-shaped, and fit a step cone-scale. By turning a stud, the four 10 gr. are added in succession, and then replaced by the 50 gr., after which the 10 gr. may be put on again. A 5 gr. and $4 \times 1$ gr. weights are manipulated in the same way. The correct weight can be read on the studs. The drawback is that the beam remains half-arrested during this weighing. H. B.

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14. *Hard Solders for Brass.* **R. Schwirkus.** (Zschr. Instrumk. 14. pp. 225–241, 1894.)—An examination of the various commercial solders for brass was undertaken by the Physikalisch-Technische Reichsanstalt in order, if possible, to find one which should be easily fusible and fairly tough and malleable. About 50 commercial or experimental solders were tested, and five were eventually obtained which appear to satisfy all requirements. These all contain a small proportion of silver instead of the more usual but noxious tin. The hardest of these contains copper 53, zinc 43, silver 4 parts, fuses in $7\frac{1}{4}$ seconds at the temperature usually employed, and allows a brass tube of 3·5 cm. diameter soldered with it to be hammered out into a flange of 1·75 cm. radius. The next, consisting of copper 48, zinc 48, and silver 4 parts, is useful for the first joints of ordinary brass. It is golden-yellow, melts in 6·9 seconds, and gives a flange of the same radius as the first. The third solder, suitable for sheets and wires, consists of copper 42, zinc 52, silver 6 parts, fuses in 6·7 seconds, and gives a flange of 2 cm. radius. The fourth, and most generally useful kind, contains copper 43, zinc 48, and silver 9 parts, is reddish-yellow, fuses easily in 6·5 seconds, and gives a flange of 1·5 cm. Finally, the fifth variety, for third solderings on the same piece, and all purposes where a soft solder is required, contains copper 38, zinc 50, and silver 12 parts, fuses in 5·5 seconds, and gives a flange of 1·3 cm. In order to prevent evaporation and burning of the zinc during the manufacture of these solders, it is fused first at the lowest possible temperature. The copper is granulated, mixed with a third of its volume of sal ammoniac, and gradually melted in the zinc. The silver is hammered into thin sheets, cut into strips and mixed with the copper. E. E. F.

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15. *Hydrometer.* **T. Lohnstein.** (Zschr. Instrumk. 14. pp. 164–170, 1894.)—Ordinary hydrometers for the determination of the specific gravity of liquids are subject to errors due to surface-tension, and if great accuracy and range are desired they must be made of large size. The author shows, on certain not unreasonable assumptions, that a hydrometer of variable immersion, which would measure specific gravities from ·7 to 2 to the fourth decimal place, would have a weight of 13 kilograms. The new hydrometer, of which a sketch is given, consists of a hollow piece of glass, cylindrical in shape, with tapered ends. The upper end is ground flat,

and when it is in exactly the same plane as t' e surface of the liquid whose specific gravity is being determined, surface-tension exercises no prejudicial action. From the centre of the upper end rises a fine rod, coincident with the axis of the cylinder; this bears a light beam at right angles to itself which extends at either end beyond the circumference of the hydrometer jar. A scale-pan hangs from this beam; it is centrally perforated and moves along the vertical support of the hydrometer jar. To determine the specific gravity of a liquid, weights—which are of such dimensions and so numbered that the calculation of the result is reduced to a minimum—are put on the pan until the upper end of the floating glass is on a level with the surface. There are many useful details which cannot be mentioned in an abstract. A. G.

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16. *Level of Variable Sensibility.* **L. Mach.** (Zschr. Instrumk. 14. pp. 175–176, 1894.)—The inner wall of the tube of a level is usually made slightly barrel-shaped by grinding, great patience and skill being required. In the level described, there is employed a cylindrical glass tube which can be curved to the extent desired, by means of pressure produced by a fine-pitched screw placed under the middle part. A. G.

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17. *Automatic Mercurial Air-pump.* **F. Neesen.** (Zschr. Instrumk. 14. pp. 125–127, 1894.)—The writer describes a shortened multiple Sprengel delivering into the vacuum of an auxiliary water-pump; the mercury is raised to its original position by means of an automatic arrangement of valves which utilises the pressure of the air to restore the head of mercury, this of course being, from the shortened nature of the pump, less than the height of the barometric column. A. G.

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18. *Photographic Recording Instrument.* **A. Raps.** (Zschr. Instrumk. 14. pp. 1–6, 1894.)—Describes a photographic recorder (patented), combined by the "Allgemeine Electricitäts Gesellschaft" with a voltmeter, which can be fitted to most instruments, and be used in daylight. A drum covered with sensitised paper revolves once in 24 hours. The light of an incandescent lamp falling through a horizontal slit, covered with glass, produces a dark line parallel to the axis of the drum, and would hence blacken the whole surface, if the pointer of the instrument did not play over the slit. The pointer, therefore, traces a bright line. A transparent disc, which can be set from outside, marked with radial lines to represent the hours and quarters, revolves in front of the slit. When an hour-line passes the light is cut off, and the hour itself is printed at the same time. By means of wires stretched vertically across the slit parallel lines can be ruled. The drum can be taken out and be covered with a hood. The developer is

poured into the hood, the drum turned by means of a crank, and taken out for fixing. Very rapid current fluctuations affect the lamp, and are recorded in that way. H. B.

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19. *Accurate Determination of Freezing-Points.* **E. H. Loomis.** (Wied. Ann. 51. pp. 500–523, 1894.)—Full details are here given of a method for determining the freezing-point of dilute aqueous solutions in which the thermometer is read to the ten-thousandth of a degree. Special attention is paid to the influence of the temperature of the surrounding medium on the observed value of the freezing-point. The solutions examined were those of urea, cane-sugar, ethyl alcohol, sodium chloride, magnesium sulphate, sulphuric acid, and phosphoric acid. The concentration varied for each dissolved substance between ·01 and ·2 gram-molecule per litre. The curves obtained on plotting molecular depression against concentration are compared with the theoretical curves deduced from the electric conductivity; large differences are here given by sulphuric acid and magnesium sulphate. The author finds no indication of the sudden changes of curvature described by Pickering. Several observers have stated that with increasing dilution the molecular depression in the case of non-electrolytes increases, and in the case of electrolytes reaches a maximum; the author's results give no support to either conclusion. The values found for sodium chloride are in close accord with those obtained by a different method by H. C. Jones.
J. W. R.

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20. *Criticism of Loomis' Paper.* **F. Kohlrausch.** (Wied. Ann. 51. pp. 524–528, 1894.)—It is here pointed out that although the results of Loomis and Jones (see previous abstract) for sodium chloride are in close agreement, this is not the case if the other results of Loomis are compared with those more recently obtained by Jones. Several possible sources of error are suggested in connection with Jones' method; these refer chiefly to his thermometer, the bulb of which contained over 200 gr. of mercury. Attention is also called to the fact that the curves for molecular depression given by Jones, unlike those of Loomis, are of a wavy character, the divergence from a smooth curve being, in many cases, much larger than the experimental errors. J. W. R.

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21. *Surface-Tension of Mercury in Capillary Tube.* **G. Quincke.** (Wied. Ann. 52. pp. 1–22, 1894.)—The author briefly reviews some recent determinations of the surface-tension of water, and maintains his previously expressed view that the angle of contact of glass and water is not generally zero. He is of opinion that the discrepancies in the values of the S.T. found by different observers are due to different amounts of impurity in the water—mainly substances dissolved from the glass,—and supports this view by the observation that the S.T. diminishes

when the water is left in contact with the glass—the time required to reach a limit depending on the extent of surface of water to be soiled. In narrow capillary tubes there is no diminution of S.T. with the time, in wider ones it is slight, and in large bubbles it reaches 10 per cent. Experiments were made with capillary tubes of different kinds of glass. The angle of contact was observed by a special form of goniometer, and found in some cases to reach 9°. The angle increases with the time that has elapsed since the tube was drawn out. In freshly drawn tubes it is very small. The S.T. when determined by means of tubes of Thuringian glass or hard Jena glass was less than when determined by means of Jena normal glass or English flint. Wide tubes of the two former kinds gave for the S.T. in mgr./mm. units 7·776, and of the two latter kinds 7·846. The S.T. of mercury, measured in the same way with tubes of normal Jena glass, was 55·78 at 17·5. The observed angle of contact was 52° 40′. The S.T. and the angle of contact diminished rapidly as the surface of the mercury became moist from contact with the air. Experiments were also made by observing the difference of heights of the liquid in the two limbs of a U-tube—one of the limbs being capillary. The results were similar to those obtained by the other method.

J. W. C.

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22. *Vapour-Tensions of Solutions.* **M. L. Marchis.** (J. de Phys. 3. pp. 193–205, 1894.)—A short account is here given of the principles of the methods employed in determining the vapour-pressures of solutions. The common sources of error in the statical method are mentioned, and Dieterici's apparatus for measuring low vapour-pressures, his calorimetric method, and Beckmann's dynamical method are briefly described. J. W. R.

23. (Journ. de Phys. 3. pp. 257–264, 1894.)—Some of the principal results which have been ascertained regarding the effects of temperature and concentration on the vapour-pressures of solutions are here summarized, and the ordinary method is indicated whereby the results of vapour-pressure observations may be used to calculate the molecular weights of dissolved substances. J. W. R.

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24. *Vapour-Tension of Hydrated Crystals.* **C. E. Linebarger.** (Zschr. phys. Chem. 13. pp. 500-508, 1894.)—A salt containing water of crystallisation has a definite vapour-pressure—the dissociation pressure. If the salt be added to a liquid in which water is soluble but its other constituent is not, the partial pressure of water in the vapour of the solution will be equal to the dissociation pressure. Suppose the relation between the partial pressure of water and its concentration in the solution to be known at different temperatures. If we now find the amount of water dissolved by the solvent, we can calculate the partial pressure of water, and thus the dissociation pressure of the salt. Experiments are described in which ether was used as solvent, and from the lowering of its boiling-point the amount of water dissolved from

various hydrated salts was calculated. The dissociation-pressures deduced for the hydrated sulphates of copper, magnesium, and zinc, and for strontium chloride, agree closely with those directly determined by Frowein. In the case of sulphate of iron and barium chloride, the method could not be made to yield trustworthy results. J. W. R.

25. *Symmetry in Physical Phenomena.* **P. Curie.** (J. de Phys. 3. pp. 393–414, 1894.)—The paper commences with a very complete classification of the various kinds of symmetry which a finite system may possess, examples being drawn from crystallography as well as from dynamics and electromagnetism. The symmetry characteristic of a physical phenomenon is defined as the maximum degree of symmetry compatible with the existence of the phenomenon. Thus the symmetry characteristic of an electrostatic field is the same as that of a cone (or other geometrical figure of revolution) which has no plane of symmetry perpendicular to its axis; while the symmetry characteristic of a magnetic field is the same as that of a rotating cylinder, which has a plane of symmetry perpendicular to its axis but no planes of symmetry passing through its axis. These conclusions are clearly established by considering the most symmetrical distribution of physical conditions consistent with the production of the respective phenomena. The author points out how considerations of symmetry may often indicate the impossibility of an assigned effect being produced under assigned conditions, and how, on the other hand, they may suggest the possibility of effects which can afterwards be sought for experimentally. Examples of the latter kind are found in Wiedemann's observations on the twisting of a magnetised wire when carrying a current, and on the E.M.F. produced in a magnetised wire when twisted; also in Hall's phenomenon. Pyro-electric and piezo-electric phenomena are also considered from the same point of view. C. V. B.

## LIGHT.

26. *Refractive Index of Aqueous Solutions of Cadmium Salts.* **R. De Muynck.** (Wied. Ann. 53. pp. 559–563, 1894.)—The experiments of Hittorf have shown that in concentrated aqueous and alcoholic solutions of $CdCl_2$ and $CdI_2$ double or triple molecules exist. The indices of refraction for such solutions and others ($CdBr_2$, $Cd(NO_3)_2$, $CdSO_4$) are measured by Pulfrich's refractometer to see whether there is any indication of complex molecules. The simple examination of the results gives no indication; the variation of the index of refraction with the number of gram-molecules in 100 grams of solution being expressed by a continuous curve. S. S.

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27. *Spectrobolometric Observations on the Emission and Absorption of Steam and Carbon Dioxide.* **F. Paschen.** (Wied. Ann. 51. pp. 1–39, 1894.)—The apparatus was mostly that described in an earlier paper (Wied. 50. p. 409, 1893). The gas is heated in a copper tube with open ends, kept full by a steady stream of gas; this is used either to radiate, or to absorb radiation from a hot iron cylinder, or an electrically heated platinum strip. Fluorite prisms are used. A preliminary result is that the carbon dioxide in the air occupying the apparatus (about 75 cm. length) produces strong absorption in certain parts of the spectrum; it is therefore not possible by ordinary means, with either prisms or gratings, to observe the spectrum of a solid source in these parts, and they have to be supplied by graphical interpolation. Curves are given showing the position and intensity of the bands: the chief band of $CO_2$ (at $\lambda = 4{\cdot}5\mu$) is of great intensity, so that 7 cm. thickness of the gas behaves like an infinite thickness. On the other hand, the lines do not broaden with increased thickness of absorbing layer, and between them there is no absorption (less than $\frac{1}{2000}$ by a 33-cm. thick layer). The position of the bands is found to vary with rise of temperature: mostly moving down the spectrum, but in one case up. The chief band of $CO_2$ varies from 29° 28′·2 to 29° 16′·5 (minimum deviation): this perhaps indicates that the bands are made up of numerous lines, some of which increase, while others decrease in intensity as the temperature changes. The position of the centre of the bands (highest degree of absorption) is not necessarily the lowest point of the energy-curve. But if $f(x)$ is the energy-curve of the continuous spectrum, and $F(x)$ the same after absorption, it is given by

$$\frac{S'(u)}{S(x)} = \frac{f'(x)}{f(x)}.$$

Hence, draw a tangent to the curve $f(x)$ and from the point where it meets the axis of $x$ draw a tangent to $F(x)$. The point of contact is the point of greatest absorption. The coefficient of absorption

is then to be calculated from the observed value of $F(x)$ and the value of $f(x)$ interpolated from neighbouring observations on the unabsorbed spectrum. R. A. L.

28. *Validity of Kirchhoff's Law of Emission.* **F. Paschen.** (Wied. Ann. 51. pp. 40–46, 1894.)—Kirchhoff's law is that the emission of any body is equal to its absorption-coefficient, multiplied by the emission of a black body. This is to be distinguished from the mere parallelism of emission and absorption due to resonance. It follows that when a gas obeys Kirchhoff's law, in a very thick layer of it the intensity of the lines of the emission-spectrum is equal to that of a black body for the same temperature and wave-length. The author uses the name "temperature-emission" for any radiation in which Kirchhoff's law is obeyed. His measurements indicate that steam and carbon dioxide, externally heated up to 1000°, give a temperature-emission, and that probably even in the Bunsen flame the same is the case; but, in agreement with E. Wiedemann, finds that in the sodium flame the temperature-emission forms only a part, and in the electric arc only a very small part, of the whole: these are consequently cases of "luminescence." The sodium flame is therefore an instance in which absorption and radiation run parallel, but Kirchhoff's law does not hold. R. A. L.

29. *Gas Spectra.* **F. Paschen.** (Wied. Ann. 52. pp. 209–237, 1894.)—On account of a new determination by Rubens (Wied. 51. p. 381, 1894) of the dispersion of fluorite, the author gives revised tables of the infra-red spectra of carbon dioxide and water-vapour. He also compares the spectra of water-vapour and water, finding a general agreement in the position of the bands, but that (i.) with an increasingly thick layer of water the bands widen, with steam this is not so; (ii.) water has and steam has not a continuous spectrum outside the bands. Replying to Pringsheim, the author contends that the spectrum of carbon dioxide cannot be called continuous, since its intensity twice changes from zero to a considerable value and back again, within a length of $\frac{1}{10}$ of the known spectrum; it is not even analogous to characteristic solid or liquid absorption-spectra like that of blood, which for moderate thicknesses lose their characteristic bands and become contiguous. He also gives numerical evidence that the emission cannot depend on dissociation. (See No. 55, p. 25.) R. A. L.

30. *Paschen's Spectrum Bolometry.* **K. Ångström.** (Wied. Ann. 52. pp. 509–514, 1894.)—The author considers Paschen's mode of calculating absorption-coefficients erroneous. He also suggests that the displacement of the absorption-bands with rise of temperature may be only an apparent movement, due to the unsymmetrical increase of intensity of the spectrum of the source of radiation, with rise of temperature. R. A. L.

31. *Spectrum Bolometry.* **F. Paschen.** (Wied. Ann. 53. pp. 287–300, 1894.)—Replying to Ångström, the author gives a detailed justification of his mode of calculating absorption-coefficients, showing it to be approximately correct, and then shows how from observations with several thicknesses of absorbing substance the true coefficient can be found freed from errors due to stray light and reflection. Paschen finds 11 per cent. of stray light in his own and 39 per cent. in Ångström's spectrum, on account of the lower dispersive power and the chromatic aberration of the lenses in the latter; and concludes that Ångström's coefficients are much too low. He also points out that one of the bands observed moves up the spectrum with rise of temperature, while the others move down; and Ångström's explanation of this phenomenon could not apply to both cases. R. A. L.

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32. *The Dispersion of Fluorite in the Ultra-Red.* **F. Paschen.** (Wied. Ann. 53. pp. 301–333, 1894.)—Discusses the merits of the various methods and materials for examining the ultra-red, with special regard to fluorite, which has, between 2 and 10 $\mu$, a very high dispersive power accompanied, unfortunately, by strong absorption, so that the examination cannot be carried beyond 10 $\mu$. In his recent researches he follows Langley's method, and adopts an arrangement similar to the one he used for his work on the emission of gases. The chief parts of his apparatus are:—slit 2, reflector (all of silver), grating (made by Rowland for Langley, 1·753 m. radius, 142·1 lines to the millim.), reflector, slit 1, fluorspar prism, reflector, bolometer, a sooted platinum-foil, $7 \times 0{\cdot}25 \times 0{\cdot}0005$ mm., 8 ohm resistance. For the greatest wave-lengths the bolometer rose by $\frac{1}{10^5}^{\circ}$ only; the more accurate work had to be done at night-time, the rooms not being quiet enough. The dispersion of the grating being ten times as large as that of the prism, slit 2 had to be widened until the ratio had been reduced to 3 : 1. The D line of the 13th order (the 20th order was distinguishable), produced by vaporising NaCl in an oxygen-coal-gas flame, was thrown on the slit, and then replaced by a light rich in ultra-red rays. As such he tried first an arc lamp, which was not steady enough; then a special incandescence lamp, with a carbon filament 5 mm. wide. Incandescent carbon is very suitable for these tests, but there were mechanical difficulties. Finally, he found that oxides are remarkably appropriate, and he employed a platinum-foil 0·01 mm. thick, painted with several coatings of iron oxide (sulphate or chloride), and heated by means of accumulators. The oxide becomes grainy crystalline, but remains suitable. He determined 34 lines, most of them between 2 $\mu$ and 9·4291 $\mu$, and concludes that Briot's dispersion formula, doubtful for 1·8 $\mu$, will certainly not hold for 3 $\mu$ and above, owing probably to absorption. H. B.

33. *The Exact Wave-Lengths of the Bands in the Ultra-Red of the Carbonic Acid and Water Spectra.* **F. Paschen.** (Wied. Ann. 53. pp. 334–336, 1894.)—This paper summarizes the results of Paschen's three papers on the emission of gases, giving the corrected wave-lengths of the carbonic-acid and water bands in the ultra-red at the temperatures 17°, 500°, 1000°, Bunsen-burner, oxyhydrogen flame. The fluorite spectrum has in general given higher values, which Paschen considers will be useful for determinations by coincidence. H. B.

34. *The Dispersion of Rock-Salt in the Ultra-Red.* **F. Paschen.** (Wied. Ann. 53. pp. 337–342, 1894.)—Paschen's dispersion-values agree with those of W. H. Julius up to 5 $\mu$, but not beyond. As Julius employed a rock-salt prism, and adopted Langley's dispersion-curve, which extends only to 5·3 $\mu$, and as the extrapolations are more likely to be incorrect than Julius' determinations, Paschen traces the dispersion of rock-salt up to 9·4 $\mu$ by comparison. He regrets to be unable to submit his deductions to experimental test; a rock-salt prism and its mountings are not at his disposal. H. B.

35. *Pseudo-Monochromasy, a New Form of Colour-Blindness.* **A. König.** (Verh. phys. Ges. 13. pp. 51–53, 1894.)—König distinguishes three systems of colour sensations:—I. The Trichromatic system: 96 per cent. of all men, 99⅔ of all women, see the Newton spectrum with two maxima of sensitiveness to change of wave-length, in the yellow and in the blue-green; white can only be produced by mixing at least two colours. II. Dichromatic system: the rest of the people see essentially a yellow band, toned down from a very deep yellow, fuller perhaps than what is known to normal eyes, to white in the blue-green; beyond this the white becomes bluish. White is here in the spectrum at the spot of maximum sensitiveness to change, and this sensitiveness is extraordinarily developed. There are two classes, differing only as to the region of maximum brightness: to the green-blind it appears to be near 610 $\mu\mu$, to the red-blind near 570 $\mu\mu$. III. Monochromatic system: known only in very few individuals, who perceive a colourless band with maximum brightness near 530 $\mu\mu$. The new type forms a transition from the monochromatic to the red-blind. On casual examination, the spectrum is described as a colourless band with maximum brightness near 570. If, however, the two ends of the spectrum are isolated and brought very near one another, a yellow and a bluish end are spoken of, which can be distinguished from the central grey. The maximum sensitiveness to change seems to occur in the blue-green. The individuals like those of III. complain of headache when their eyes are strained. H. B.

36. *Reflection from Glass.* **B. Walter.** (Wied. Ann. 52. pp. 762–776, 1894.)—A transparent plate employed to direct a beam of light normally upon a mirror, and after reflection to

transmit it to the eye, is termed by the author a "Gauss' plate." He investigates theoretically the intensity of the light reaching the eye in a number of cases, and points out that a crown-glass plate, if inclined at about 10° to the beam, gives an intensity 2·8 times as great as that obtained at the usual angle of 45°.

L. R. W.

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37. *Elliptic Polarisation of Light from a Transparent Reflector.* **P. Drude.** (Wied. Ann. 53. pp. 69–76, 1894.)—The paper deals briefly with objections that have recently been made by Volkmann and Bonasse to the theory that the elliptic polarisation of light reflected from a transparent medium is due to the existence of a surface-layer with optical properties different from those of the inner part of the medium, and answers some criticisms by K. E. F. Schmidt of the author's experiments on the polarisation of light reflected from Iceland spar. J. W. C.

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38. *Specific Inductive Capacities of Solid, and Refractive Indices of Fused Salts.* **L. Arons.** (Wied. Ann. 53. pp. 95–108, 1894.)—The specific inductive capacities of fused nitrates of potassium and sodium, and of a mixture of the two in molecular proportions, are determined by Schiller's method. The plates of the liquid condenser are immersed in the fused salt, which is then allowed to solidify. In the case of $KNO_3$, the spec. ind. cap. diminishes from 5·73 to 2·56 in seven days, the decrease being most rapid in the first few hours. The spec. ind. cap. of $NaNO_3$ falls only very slightly, and the mixture of the two nitrates shows an intermediate rate of decrease. The author finds an explanation of these phenomena in the fact that the crystallisation of $KNO_3$ changes from the rhombic to the hexagonal system as it approaches the fusing-point, and supposes it to have a much higher spec. ind. cap. in the latter form. Bouty's hypothesis regarding the coexistence of conductivity and dielectric power is not sufficiently supported by the behaviour of the mixture. The refractive indices of $KNO_3$ and $NaNO_3$ are found to be 1·404 and 1·455 respectively, for yellow light. E. E. F.

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39. *Optical Axis of Eye.* **W. C. Röntgen.** (Wied. Ann. 52. pp. 589–593, 1894.)—When an observer looks with one eye through the hypothenuse face of a right-angled prism, he sees an image of his eye with the image of the prism edge crossing it. The author finds that the image of the edge always goes through a point on the pupil which is not at its centre, but in most cases nearer the nose; and hence concludes that the optical axis of the eye is not its axis of figure—a fact previously discovered in another way by Helmholtz. If a telescope with vertical and horizontal cross-wires in the eyepiece be focussed for parallel rays, and be directed towards such a prism with its edge vertical and with the hypothenuse face turned towards the telescope, the cross-wires remain in coincidence with their image when the prism is turned about its edge. If there is any inaccuracy in the right angle, the

image of the vertical cross-wire will be displaced, and if the three edges of the prism are not parallel, the image of the horizontal wire will be displaced: whence we have a test of the accuracy of the grinding of the prism or of the setting of two mirrors at right angles. If the cross-wires be turned round at a certain rate, and the prism itself be turned in the same direction at half the rate, about an axis perpendicular to the hypothenuse face, the image of the cross-wires stands still. The author suggests that this fact may be of use in making observations on bodies in rapid rotation.

J. W. C.

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40. *Afterglow in Vacuum-Tubes, and Incipient Incandescence.* **C. Kirn.** (Wied. Ann. 52. pp. 381–384, 1894.)—The first light perceived from solid bodies as the temperature is raised to the stage of incandescence was found by H. F. Weber to be of a cloudy grey colour, corresponding in the spectrum to the bright portion where green and yellow coalesce. It is a band which broadens on either side as the temperature increases. (The dark red glow, which was formerly regarded as the initial visible emission, belongs to a higher temperature of the body.) Experiments by Stenger and Ebert have shown that the eye has maximum sensitiveness for rays belonging to the particular band between green and yellow, here described. Kirn now investigates the converse case, by studying the afterglow of Geissler tubes. When the electric discharge ceases, the light begins to disappear from the negative end of the tube, the evanescence then slowly creeps towards the positive electrode. The weak spectrum obtained from this afterglow is at first continuous, but rapidly contracts from both ends—more from the blue than from the red—into a band whose locus in the spectrum corresponds to about 555–495$\mu\mu$. The final evanescence is from a spectral band closely associated with the E line; it is almost coincident with the position of maximum retina-sensitiveness, and is identical with the band of initial visible emission.

R. A.

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41. *Half-shade Polarisers.* **F. Lippich.** (Zschr. Instrumk. 14. p. 326, 1894.)—Professor Lippich of Prague is further improving his half-shade polariser, with which readings to 8″ in 25° have been taken. Looking from above, the tube contains the large prism 1, two smaller prisms 2, 3, one fixed, the other turning about the axis like 1, and the diaphragm. The field shows three bands, 2, 1, 3. If the analyser is turned, 1 will differ from the other two; by turning 3, the discrimination can be carried still further.

H. B.

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42. *Durable Thin Plates with Newton's Rings.* **F. Kohlrausch.** (Wied. Ann. 51. pp. 351–352, 1894.)—These are produced by blowing the end of a double capillary tube—a tube with two bores side by side—into a bulb. The membrane bisecting the bulb shows brilliant coloured rings whose order varies with the temperature at which they are produced. These membranes are

easily destroyed by slight concussions, but at higher temperatures black membranes are produced of extreme tenuity, which are very fairly stable. After they are formed, the tube is exhausted several times and then sealed. Some of the black spots thus obtained are 7 mm. in diameter. E. E. F.

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43. *Sensitiveness of Human Retina. Preliminary Notice.* **A. König** and **J. Zumft.** (Verh. phys. Ges. 13. p. 56, 1894.)—By a modification of Purkinje's method, König and Zumft have established that the perceptions of the different colours occur in different layers of the retina, the larger wave-lengths affecting the outer layers. Apparently yellow and red only can be perceived in the same layer. H. B.

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44. *The Meaning of Lines of Force and Surfaces of Potential in Optics.* **H. Ruoss.** (Wied. Ann. 53. pp. 77–84, 1894.)—There is a close analogy between a charge of electricity and a source of light, the action of each obeys the law of the inverse square; for this reason the solutions of problems in Electrostatics can be directly applied to solve problems in Illumination, *e. g.* to find shadowless surfaces and surfaces of maximum illumination. A shadowless surface is one which does not produce shadows: it is equally illuminated on each side; a small Bunsen disc placed on such a surface would not show the grease spot. To find, at a given point, the tangent plane to the surface of maximum illumination, the disk must be twisted about until the distinction between the spot and the surrounding part is a maximum. A surface of equal potential corresponds to a surface of maximum illumination, and the surface of a tube of force corresponds to a shadowless surface; although, in comparing, certain reservations are necessary depending on the fact that surfaces, as actually dealt with in practice, must be taken as more or less opaque. As a practical example, use is made of fig. 1 at the end of Vol. I. of Clerk Maxwell's 'Electricity,' which shows the lines of force and surfaces of equal potential round two charges of positive electricity; there are some necessary additions; and by the examination of the figure one can tell at a glance the manner in which the space round two sources of light of appropriate intensities is illuminated. A. G.

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45. *Phase-change by Reflection from Thin Metallic Deposits.* **W. Wernicke.** (Wied. Ann. 52. pp. 515–535, 1894.)—The author is able to draw conclusions as to the constitution of excessively small quantities of substances (such as silver, silver oxide) deposited on a glass plate, by observing the change of phase they produce in reflecting light. He distinguishes between the "molecular" state of the freshly-deposited body and the "coherent," obtained by burnishing; and finds the refractive index and absorption different for the two. In the coherent state the region of chief absorption is lower down the spectrum than for the molecular: the refractive index (of metals and dyestuffs) is anomalous, being

very high below, and very low above the region of absorption. Thus in the visible spectrum, for silver it is 4 in the molecular and $\frac{1}{4}$ in the coherent state. R. A. L.

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46. *Some Fluorescence Phenomena.* **Edgar Buckingham.** (Zschr. phys. Chem. 14. pp. 129–148, 1894.)—The writer sets himself the task of discovering whether fluorescence—like colour, the power of refracting light and of turning the plane of polarisation—is a property of ions as well as of ordinary molecular substances. He finds it is. Stokes' method of observing fluorescence by allowing light from the upper end of the spectrum to fall on the body examined, and looking at it through yellow glass, was employed; quantitative results were not aimed at. An aqueous solution of eosin ($C_{20}H_8Br_4O_5$) is first examined: dilution, which increases dissociation, increases the fluorescence; the addition of acids, which diminishes dissociation, diminishes the fluorescence; bases and neutral salts act as theory indicates. A few experiments are made with $\beta$-naphthylamine disulphonic acid, but the substances most thoroughly examined are the hydrochloride, acetate, sulphate, nitrate, and bisulphate of quinine. The conclusion arrived at is that the fluorescence of aqueous solutions of quinine salts is mainly caused by divalent quinine ions, although monovalent may be present and participate in the action to a feebler extent; in the case of an alcoholic solution of the bisulphate, the fluorescence is caused by monovalent quinine ions. With respect to the peculiar action of the compounds of the halogens on the fluorescence of quinine salts, the writer concludes that it *is* due, in some way, to the halogen ions, and that it *is not* due to the absorption by the ions of the rays which produce fluorescence or to the formation of polymolecules. A. G.

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47. *On the Rapidity of the Photo-electric Phenomena of Selenium.* **Q. Majorana.** (Nuov. Cim. 34. pp. 267–275, 1894.)—Selenium cells were made of alternate plates of brass and mica, and the surface formed by one set of edges, which had an area of 1 sq. cm., was heated to the melting-point of selenium (211°) and coated with a thin layer of this substance by means of a selenium pencil. It was allowed to cool very slowly in a paraffin bath. One of these cells had a resistance of 258,100 ohms in the dark, and 86,700 ohms when exposed to sunlight deprived of obscure radiation. The cell was momentarily illuminated by such sunlight by means of a rotating mirror, and the change of resistance measured at different intervals after the illumination had ceased. This gave the rapidity with which the selenium recovered from the effects of illumination. With the exposure employed, it was found that the resistance fell to 200,000 ohms during illumination, and that it had half recovered in about $1\frac{1}{2}$ seconds. The original value was not attained for another 8 seconds at least. After stronger or more protracted illumination, the recovery would have been more rapid. E. E. F.

## HEAT.

48. *Thermodynamic Potential for a Heterogeneous System and Application to van der Waals' Theory and the Law of Boiling-Points.* **E. Riecke.** (Wied. Ann. 53. pp. 379-391, 1894; Nachr. Göttingen, 2. 1894).—Five sections are occupied in deducing, with no appreciable change from Gibbs' method, certain theorems with respect to the equilibrium of a heterogeneous system which Gibbs gave in his well-known memoir. Then, with van der Waals' characteristic equation for a simple gas in the form

$$p=\mathrm{N}m\mathrm{R}\mathrm{T}(v-b)^{-1}-2\pi\mathrm{N}^2m^2\mathrm{A}v^{-2},$$

where N is the number of molecules in the volume $v$, $m$ their mass, and R, A, $b$ constants, the known expressions for the energy $\epsilon$ and entropy $\eta$ in terms of $v$ and T are obtained on the assumption of the constancy of $c$, the constant-volume specific heat; and by elimination of T the equation

$$\epsilon=\mathfrak{A}c\mathrm{N}m(v/\mathrm{N}m-\beta)^{1-k}e^{\eta/c\mathrm{N}m}-2\pi\mathrm{A}\mathrm{N}^2m^2v^{-1}$$

results, wherein $\beta\equiv b/\mathrm{N}m$, $\mathfrak{A}$ is Joule's equivalent and $k$, the ratio of the constant-pressure to the constant-volume specific heat, is $1+\mathrm{R}/\mathfrak{A}c$. The thermodynamic potential of the gas at once follows as

$$\mu\equiv\frac{\partial\epsilon}{\partial\mathrm{N}m}=\mathfrak{A}c\mathrm{T}(1-\log\mathrm{T})+pv/\mathrm{N}m-\mathrm{R}\mathrm{T}\log(v/\mathrm{N}m-\beta)-2\pi\mathrm{A}\mathrm{N}mv^{-1},$$

which takes the form

$$\mu/\mathrm{R}\theta_0-\mathfrak{T}=\{\phi/(\phi-\tfrac{1}{3})-\log(\phi-\tfrac{1}{3})\}\theta-9/4\phi,$$

with van der Waals' mode of writing $\phi\equiv v/\phi_0$, $\theta\equiv\mathrm{T}/\theta_0$, $\pi\equiv p/\pi_0$, where $\phi_0$, $\theta_0$, $\pi_0$ are the values of $v$, T, $p$ in the critical state so that

$$b\equiv\mathrm{N}m\beta=\tfrac{1}{3}\phi_0,\quad \mathrm{N}m\mathrm{R}=8\pi_0\phi_0/3\theta_0,\quad 2\pi\mathrm{N}^2m^2\mathrm{A}\equiv 3\pi_0\phi_0^2,$$

and on putting

$$\mathfrak{T}\equiv\{(k-1)\log(8\pi_0/3\mathrm{R})-k\log\theta_0+1-\log\theta\}\theta/(k-1).$$

Thus, not only, as van der Waals showed, is the reduced pressure for all gases the same function of the reduced volume and reduced temperature, since

$$\pi=8\theta/(3\phi-1)-3\phi^{-2},$$

but so, too, is the magnitude $\mu/\mathrm{R}\theta_0-\mathfrak{T}$.

If, then, for a given value of $\theta$ the values of $\pi$ and $\mu/\mathrm{R}\theta_0-\mathfrak{T}$ are plotted for all values of $\phi$, the reduced saturation-pressure and the reduced specific volumes for both liquid and vapour at this reduced temperature may be graphically determined by finding the two isometrics whose intersections with each curve have equal ordinates, since $\pi$ and $\mu$ have the same values for a liquid and vapour that are in equilibrium. In this way Riecke determined the values of $\pi$, $\phi_1$, $\phi_2$ for $\theta=1$, ·95, ·90, ... ·60, and compared

them with the results for fluorbenzene deduced from Young's experiments, finding very wide differences: thus for $\theta = \cdot 95$ the theoretical values are ·807, ·693, 1·78 respectively, while the actual values are ·678, ·570, 2·82; and for $\theta = \cdot 7$ the theoretical values are ·199, ·466, 7·75, while the actual values are ·055, ·396, 44·0: whence this method too shows v. d. Waals' isothermal to be inexact. R. E. B.

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49. *Thermodynamics of Imbibition.* **E. Riecke.** (Wied. Ann. 53. pp. 564–592, 1894; Nachr. d. K. Gesellsch. d. Wiss. zu Göttingen, no. 1, 1894.)—This is a thermodynamic study of the absorption of water by an organic substance, with the view of elucidating the character of muscular action. The energy and entropy of a mass $m_1$ of non-saturated aqueous vapour in volume $v_1$ at pressure $p$ and absolute temperature T, for which $pv_1 = m_1 \mathrm{RT}$,

are $\quad \mathrm{E}_1 = \mathfrak{A} m_1 c \mathrm{T}, \quad \eta_1 = m_1 c \log . p (v_1/m_1)^k,$

so that $\quad \mathrm{E}_1 = \mathfrak{A} c m_1{}^k e^{\eta_1/m_1 c} / \mathrm{R} v_1{}^{k-1},$

and thus $\quad \mathrm{RT} \equiv (\partial \mathrm{E}_1/\partial \eta_1)\mathrm{R}/\mathfrak{A} = e^{\eta_1/m_1 c}(m_1/v_1)^{k-1},$

and the potential is

$$\mu_1 \equiv \partial \mathrm{E}_1/\partial m_1 = \mathfrak{A}\mathrm{T}(\mathrm{R} + c - \eta_1/m_1) = \mathfrak{A}\mathrm{T}\{(\mathrm{R}+c)(1 - \log \mathrm{RT}) + \mathrm{R} \log p\}.$$

Again, for a mass M of an isotropic absorbing substance of volume $v_2$ containing $m_2$ absorbed water, we have

$$d\mathrm{E}_2 = \mathfrak{A}\mathrm{T} d\eta_2 - p dv_2 + \mu_2 dm_2 + \mathbf{M} d\mathrm{M},$$

so that, as the potential of the absorbed water must depend on the relative proportions of water and substance,

$$\mu_2 \equiv \partial \mathrm{E}_2/\partial m_2 = f(\eta_2/\mathrm{M},\ v_2/\mathrm{M},\ m_2/\mathrm{M}) = \phi(p,\ \mathrm{T},\ m_2/\mathrm{M});$$

and as $\mu_2 = \mu_1$ for equilibrium,

$$\phi(p,\ \mathrm{T},\ m_2/\mathrm{M}) = \mathfrak{A}\mathrm{T}\{(\mathrm{R}+c)(1 - \log \mathrm{RT}) + \mathrm{R} \log p\},$$

or the absorption $m_2/\mathrm{M}$ by a body in non-saturated vapour is a function of $p$ and T.

$\mathrm{E}_2$ being a homogeneous function of the first degree, we have

$$\mathrm{E}_2 = \eta_2 \frac{\partial \mathrm{E}_2}{\partial \eta_2} + v_2 \frac{\partial \mathrm{E}_2}{\partial v_2} + m_2 \frac{\partial \mathrm{E}_2}{\partial m_2} + \mathrm{M} \frac{\partial \mathrm{E}_2}{\partial \mathrm{M}} = \mathfrak{A}\mathrm{T}\eta_2 - p v_2 + \mu_2 m_2 + \mathbf{M}\mathrm{M},$$

whence also $\quad \mathfrak{A}\eta_2 d\mathrm{T} - v_2 dp + m_2 d\mu_2 + \mathrm{M} d\mathbf{M} = 0;$

and, similarly, $\quad \mathfrak{A}\eta_1 d\mathrm{T} - v_1 dp + m_1 d\mu_1 \qquad = 0;$

but $d\mu_2 = d\mu_1$, and therefore

$$\begin{aligned} d\mathbf{M} &= \{\mathfrak{A}(\eta_1/m_1 - \eta_2/m_2) d\mathrm{T} - (v_1/m_1 - v_2/m_2) dp\} m_2/\mathrm{M} \\ &= \mathfrak{A} q \mathrm{Q}/\mathrm{T} \,.\, d\mathrm{T} - q u \, dp, \end{aligned}$$

where Q is the heat required to vaporise 1 gram of the absorbed water at the temperature T when the absorption is $q \equiv m_2/\mathrm{M}$, and $u$ is its ensuing change of volume; hence

$$\mathfrak{A}\partial(q\mathrm{Q})/\partial p = -\mathrm{T}\partial(qu)/\partial \mathrm{T}.$$

Now experiments on seaweed show that the absorption is of the form $q=ap-bp^2-cp\mathrm{T}$, and $u=v_1/m_1=\mathrm{RT}/p$, whence

$$\mathrm{Q}=-\frac{\mathrm{RT}(a-\frac{1}{2}bp-2c\mathrm{T})}{\mathfrak{A}(a-bp-c\mathrm{T})}.$$

[The author gave a less approximate value by neglecting $\partial\mathrm{Q}/\partial p$ in the integration. We may further deduce $\mathbf{M}=-\mathrm{RT}p(a-\frac{1}{2}bp-c\mathrm{T})$.] The values of Q calculated from experiments on different seaweeds agree but little except in giving Q positive. The theory is then extended to the general case of an elastic absorbing substance under stress, which is of too mathematical a character to be represented in an abstract. R. E. B.

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50. *The Ratio of Diminution of Section to Longitudinal Strain as a Temperature Function.* **A. Bock.** (Wied. Ann. 52. pp. 609–620, 1894.)—Bock used the apparatus of Kirchhoff (Pogg. Ann. 1859, vol. 108. p. 369), but heated in an air-bath consisting of two iron cases with a clear space of 5 cm. width. The loads could be applied by means of rods passing through the hollow feet of the inner case, which was 45×20×20 cm., and fixed below to two diagonal pieces of wood. A bar of hard English steel 3·38 mm. thick gave a ratio $\mu=0{\cdot}282$ at 22°; heating up to 100° C. had little influence. Another steel in normal state, *i. e.* kept at dull red heat for several hours each day during one week, gave $\mu=0{\cdot}256$ at 20°, with an increase of 2 p. c. for 100°; a copper wire, 3·82 mm., $\mu=0{\cdot}340$ at 20°, increase of 4 p. c. for 100°; a silver wire, 4·36 mm., $\mu=0{\cdot}346$, increase of 10 p. c. for 100°; a nickel bar, 5·00 mm. thick, $\mu=0{\cdot}329$, increase of 2·4 p. c. Temperatures above 160° do not seem to have been employed. The results are not particularly concordant, owing perhaps to thermoelectric after-reactions and other causes. H. B.

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51. *Boiling-Points.* **U. Dühring.** (Wied. Ann. 52. pp. 556–588, 1894.)—A claim of priority, accompanied by criticism of Ramsay and Young's statement of the law of corresponding temperatures. Tables are given comparing 15 substances with water, and showing the variation in his own and R. & Y.'s coefficients. The author gives the law in the form

$$\frac{t'-s'}{t-s}=q,$$

where $t$ and $s$ are the boiling-points of one substance at pressures $p_1$ and $p_2$, $t'$ and $s'$ are the boiling-points of the other substance at the same pressures, and $q$ is called the "specific factor" and is constant to about the same degree as the specific heat. R. A. L.

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52. *Thermodynamic Interpretation of Maxwell's Law.* **L. Natanson.** (Zschr. phys. Chem. 14. pp. 151–154, 1894.)—Let $n_i$ represent the number of the N molecules of a gas at P and

T with velocities between certain narrow limits, $\mu_i$ the mass of each, $\varphi_i$ their thermodynamic potential per unit mass; then $N=\Sigma . n_i$, and the thermodynamic potential of the system is $\Phi=\Sigma . \mu_i n_i \phi_i$. Now

$$\phi_i=\zeta_i-RT\mu_i^{-1}\log(N/n_i),$$

where $\zeta_i$ depends on T, P only; and it is easily shown that

$$\frac{\partial\Phi}{\partial n_i}=\mu_i\phi_i=\mu_i\zeta_i-RT\log(N/n_i). \quad . \quad . \quad . \quad . \quad (1)$$

But for equilibrium we have

$$\Sigma . (\partial\Phi/\partial n_i)\delta n_i=0;$$

and if $\delta n_h$ of the class $(h)$ collide with $\delta n_k$ of the class $(k)$, their classes being thereby changed to $(r)$ and $(s)$, we shall have

$$\frac{\partial\Phi}{\partial n_h}\delta n_h+\frac{\partial\Phi}{\partial n_k}\delta n_k+\frac{\partial\Phi}{\partial n_r}\delta n_r+\frac{\partial\Phi}{\partial n_s}\delta n_s=0,$$

where $$\delta n_r=-\delta n_h=-\delta n_k=\delta n_s;$$

so that $$\frac{\partial\Phi}{\partial n_h}+\frac{\partial\Phi}{\partial n_k}=\frac{\partial\Phi}{\partial n_r}+\frac{\partial\Phi}{\partial n_s},$$

or, by (1),

$$\log(n_r n_s/n_h n_k)=(\mu_h\zeta_h+\mu_k\zeta_k-\mu_r\zeta_r-\mu_s\zeta_s)/RT,$$

and therefore $$n_h n_k=n_r n_s$$

since $\mu_h=\mu_r$, $\zeta_h=\zeta_r$, &c., as the $(r)$ and $(h)$ molecules, &c., differ only in velocity. This equation is the fundamental form of Maxwell's law, from which the usual form is easily deduced.

R. E. B.

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53. *Thermodynamics of Molecular Pressure.* **G. Bakker.** (Zschr. phys. Chem. 13. pp. 145–154, 1894.)—The external pressure $p$ is looked upon as balancing the excess of a thermal pressure $\Theta$ over a molecular pressure K, or $p=\Theta-K$. The *assumption* of $\Theta=Tf(v)$ at once gives

$$K=T\phi(v)+T\int_T^\infty dT(\partial\epsilon/\partial v)_T/T^2,$$

where, however, $\phi(v)$ must be 0, or otherwise at constant density K would increase indefinitely with T, since its second term is less than $ET\int_T^\infty dT/T^2$ or E, and is therefore finite, E being the greatest value of $(\partial\epsilon/\partial v)_T$ between T and $\infty$; consequently,

$$K/T=\int_T^\infty dT(\partial\epsilon/\partial v)_T/T^2,$$

$$p/T=f(v)-\int_T^\infty dT(\partial\epsilon/\partial v)_T/T^2.$$

[It may be noted that this characteristic is absolutely general, and was so given by Lord Kelvin in 1851.]

Since $$p=\mathrm{T}(\partial\eta/\partial v)_{\mathrm{T}}-(\partial\epsilon/\partial v)_{\mathrm{T}},$$

we shall have

$$\Theta=\mathrm{T}(\partial\eta/\partial v)_{\mathrm{T}}=\mathrm{T}(\partial p/\partial\mathrm{T})_{v} \quad \text{and} \quad \mathrm{K}=(\partial\epsilon/\partial v)_{\mathrm{T}}$$

*if* we assume $p=\mathrm{T}f(v)-\psi(v)$; in which case

$$\mathrm{K}=\psi(v), \quad \epsilon=\int\psi(v)dv+\chi(\mathrm{T}), \quad \text{and} \quad \eta=\int f(v)dv+\omega(\mathrm{T}).$$

A particular case of this is van der Waals', in which $\mathrm{K}=a/v^2$, $a$ having for a mixture of gases a form that is given in the memoir: and the author considers another to be that wherein the molecules are unchangeable and attract each other with forces depending on their distance apart only, so that the molecular pressure is a function of density only; no reason, however, being given for assuming that no work against molecular action is done during isometric heating. On integrating by parts the general expression for K/T, with the assumption that K is negligible at very high temperatures, we obtain

$$\mathrm{K}=-(\partial\psi_1/\partial v)_{\mathrm{T}},$$

where $\psi_1\equiv\epsilon_1-\mathrm{T}\eta_1$ and $\epsilon_1$, $\eta_1$ are the isometric changes of energy and entropy between T and $\infty$; for $(\partial\epsilon/\partial\mathrm{T})_{v}\equiv c$, the constant-volume specific heat, $\eta_1\equiv\int_{\mathrm{T}}^{\infty}d\mathrm{T}c/\mathrm{T}$, and by an isometric-isothermal cycle it is easily proved that $(\partial\epsilon_1/\partial v)_{\mathrm{T}}\equiv-(\partial\epsilon/\partial v)_{\mathrm{T}}$. As we have also $p=-(\partial\psi/\partial v)_{\mathrm{T}}$ where $\psi\equiv\epsilon-\mathrm{T}\eta$, the free energy, we may write $\Theta=-(\partial\psi_2/\partial v)_{\mathrm{T}}$ where $\psi_2\equiv\psi+\psi_1$. [In the memoir $\psi$ and $\psi_2$ are used with changed sign, and $\psi_1$, $\psi_2$ are wrongly described as changes of free energy.] $\psi_1$ is then calculated for van der Waals' case. Lastly, K is practically *assumed* to be more generally represented by $(\partial(\epsilon-i)/\partial v)_{\mathrm{T}}$, which leads to $\Theta=(\partial(\mathrm{T}\eta-i)/\partial v)_{\mathrm{T}}$, $i$ denoting internal energy of the molecules. R. E. B.

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54. *The Density of Saturated Vapour and the Law of Solidification and Evaporation of the Solvent.* **F. M. Raoult.** (Zschr. phys. Chem. 13. pp. 187–190, 1894.)—From Arrhenius' theoretical law, $\Delta\mathrm{M}'/\mathrm{P}=\cdot01988\,\mathrm{T}^2/\mathrm{L}$, follows at once Raoult's experimental law as modified by Raoult and Recoura, viz. $d'/d=(1-f'/f).100/\mathrm{P}.\mathrm{M}'/\mathrm{M}$, where $\Delta$ is the elevation of the absolute boiling-point T of a solvent, of molecular weight M, and $1-f'/f$ the relative depression of its vapour-pressure, by the solution of P per cent. of a substance, of molecular weight M', $d'/d$ being the ratio of the actual and theoretical densities of the vapour and L the heat of vaporization. For $f-f'\doteq\Delta(df/d\mathrm{T})$, and Clapeyron's equation gives

$$\mathrm{L}=\mathrm{T}(u'-u)\frac{df}{d\mathrm{T}}\doteq\frac{\mathrm{T}}{f}\cdot\frac{df}{d\mathrm{T}}\cdot fu'\doteq\frac{\mathrm{T}}{f}\cdot\frac{df}{d\mathrm{T}}\cdot\frac{1\cdot988\,\mathrm{T}}{\mathrm{M}}\frac{d}{d'},$$

since for M grams of any perfect gas $pv=1{\cdot}988\,T$ calories. Further, the above modified law taken at the absolute *freezing*-point T with van't Hoff's theoretical law, $CM'/P=\cdot01988\,T^2/L$, where C is the depression of the freezing-point by the solution and L is the latent heat of *fusion*, gives an improved modification of Guldberg's experimental law, viz.

$$d'/d=1{\cdot}988\,(1-f'/f)\,T^2/CML. \qquad \text{R. E. B.}$$

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55. *Paschen's "Emission of Hot Gases."* **E. Pringsheim.** (Wied. Ann. 51. pp. 441–447, 1894.)—The author gives a personal explanation as to the views attributed to him by Paschen; and then remarks that the emission-spectrum of carbon dioxide and steam, from their extent, may be regarded rather as "continuous," and so obeying the same conditions as those of solids and liquids. With regard to Paschen's argument that emission is not due to dissociation, the author considers the proof inadequate, but without maintaining the converse view. (See No. 29, p. 13.) R. A. L.

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56. *Law of Thermodynamic Correspondence.* **J. de Kowalski.** (J. de Phys. 3. pp. 159–162, 1894.)—Duclaux showed that on adding to two liquids which do not mix a third liquid which dissolves both, a homogeneous liquid results, called a ternary solution. Denoting by $q$, Q the least masses of an active liquid ($c$) which, added to unit mass of a liquid ($a$), permit it to form a homogeneous liquid, of total volume $w$, with $m-1$ mass-units of a liquid (A) and to mix with (A) in all proportions respectively, the author calculates, from Pfeifer's experiments with ethyl alcohol and water for liquids ($c$) and (A), the values of $w$ for each of nine liquids ($a$) for the values $\frac{2}{8}$, $\frac{3}{8}$, . . . $\frac{7}{8}$ of $q/Q$, and finds that the ratio of the values of $w$ for any two of the liquids with the same value of $q/Q$ is independent of $q/Q$. For example, with ethyl propionate and methyl valerate he finds ·67, ·64, ·64, ·65, ·64, ·64 for this ratio, or ·65 in the mean. Thus $w$ is of the form $af(q/Q)$, where $a$ is a constant which differs for different substances, the function $f$ being the same for all; and hence the conclusion that *the law of thermodynamic correspondence subsists even in the case of ternary mixtures.* Q is called the *critical* quantity. R. E. B.

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57, 58. *On the Specific Heat of Gases.* **S. Lussana.** (Nuov. Cim. 34. pp. 41–43, & 130–141, 1894.)—In order to avoid the necessity of preparing a large quantity of gas, an arrangement was adopted which permitted the repeated use of the same quantity. Two steel cylinders partly filled with mercury communicated at the bottom by a flexible tube. The tops communicated with the ends of a copper tube with two worms along its length, one of which was immersed in a heating oven, and the other in a calorimeter. By a suitable arrangement of taps the gas contained in one cylinder could be driven through the worms by raising the

other cylinder and thus emptying the mercury into the first, after which the gas was replaced in the first cylinder by altering the taps and lowering the second. Pressures ranging from 5 to 40 atmospheres were employed. The chief results are the following :—

| Gas. | Spec. heat at constant pressure of 1 atmosphere. | Increase per atmosphere. |
|---|---|---|
| Air ..... | 0·2371 | 0·00150 |
| Hydrogen ..... | 3·4025 | 0·0133 |
| Methane ..... | 0·5915 | 0·0035 |
| $CO_2$ ..... | 0·2013 | 0·00192 |
| Ethylene ..... | 0·4039 | 0·00160 |
| $N_2O$ ..... | 0·2248 | 0·00184 |

E. E. F.

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59. *The Specific Heat of Water at Constant Volume.* **A. Bartoli** and **E. Stracciati.** (Nuov. Cim. 34. pp. 113–126, 1894.)—The authors have calculated the specific heat at constant volume from their own values for that at constant pressure, with the aid of Pagliani and Vicentini's results for the compressibility, and Rossetti's for the expansion of water, assuming 428 m.-kg. as the mechanical equivalent of heat. Some of the values, referred to the specific heat of water at 15° under constant pressure, are given below :—

| | | | |
|---|---|---|---|
| 0° .... | 1·00592 | 20° .... | 0·99320 |
| 5° .... | 1·00380 | 25° .... | 0·98984 |
| 10° .... | 1·00046 | 30° .... | 0·98697 |
| 15° .... | 0·99683 | 35° .... | 0·98490 |

The ratios of the specific heats at constant pressure to those at constant volume are, for the same temperatures :—

| | | | |
|---|---|---|---|
| 0° .... | 1·00071 | 20° .... | 1·00628 |
| 5° .... | 1·00002 | 25° .... | 1·01032 |
| 10° .... | 1·00106 | 30° .... | 1·01516 |
| 15° .... | 1·00318 | 35° .... | 1·02059 |

E. E. F.

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## SOUND.

60. *Frequency at High Pitches.* **F. Melde.** (Wied. Ann. 52. pp. 238–262, 1894.)—To determine the frequency of tuning-forks of high pitch—up to 2000 vibrations per second—without the intervention of the ear, the author arranges them to communicate the vibrations to a rectangular metal bar 320 mm. long by 1·5 thick, on which sand is strewn. The vibrating length of the bar can be adjusted till nodes are formed "hair-sharp." The frequency of the bar is calculated from its dimensions, by the aid of previous experiments with a tuning-fork of known (low) pitch, giving a smaller number of nodes on the bar. Forks by Appun and König were tested, and some of those of above 8000 vibrations found to be considerably wrong, showing the untrustworthiness of ear observations on so high pitch. R. A. L.

## ELECTRICITY.

61. *Experiments on the Origin of Frictional Electricity.* **C. Christiansen.** (Wied. Ann. 53. pp. 401–431, 1894.)—Christiansen starts from Helmholtz's views on the analogy between frictional and contact electricities. He applies a metallic disc, covered with an insulator, to a glass tray filled with mercury, inserts a galvanometer between the disc and the mercury, and notes the deflections produced each time when the insulator and the mercury are brought into contact or separated from each other. When applied the first time, no deflection is observed, since contact between an insulator and a conductor cannot produce a current. In a modified form of apparatus a glass tube, 15 cm. long, 3–6 mm. wide, coated inside with the respective insulator, its central part outside being covered with tin-foil (or some metallic sleeve), was joined to another glass tube connected by rubber tubing with a mercury cistern: the tin-foil and a platinum wire fused into the second tube formed the electrodes. Amalgams of Zn and Cu were produced by pouring a little sulphate on the mercury. A great many insulators—resins, paraffin, camphor, &c.—were tried in air, oxygen, hydrogen, and carbonic acid; water-vapour had hardly any effect but to stop all action when the atmosphere was saturated. In all cases the insulator became positive when oxygen was absent. In the presence of oxygen, pure mercury made the insulators negative; an amalgam electrified them positively. The author concludes that mere friction cannot produce electricity. There would always be chemical action, and a double film of + kations and − anions would form. He would distinguish between:—(1) Insulators or Dielectrics, in which the ions are immobile or capable of oscillations only; (2) Metals, whose ions can move or at any rate easily exchange their charges; (3) Electrolytes, whose ions can move with more or less friction; (4) Hydrides, like water, which contain a few ions only. H. B.

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62. *Distribution of Induction in Strained Nickel Wire.* **H. Nagaoka.** (Wied. Ann. 53. pp. 481–486, 1894.)—The distribution of magnetisation along a nickel wire which is kept in a constant field and undergoes reversals of polarity under the simultaneous influence of longitudinal pull and cyclic twist is investigated. The author concludes (1) that the magnetisation is symmetrical about the middle of the wire unless the total magnetisation is very small; (2) that a genuine reversal of polarity all along the wire is finally produced; (3) that with small total magnetisation the distribution is complicated, the wire behaving like three separate magnets placed end to end. L. R. W.

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63. *Variations of Dimensions of Iron, Nickel, and Cobalt when Magnetised.* **H. Nagaoka.** (Wied. Ann. 53. pp. 487–498, 1894.)—The observations already made by the author upon wires

are here extended to prolate spheroids, in order to obtain results which, on account of the gain in uniformity of magnetisation, can be more easily interpreted. The changes of length are measured by an optical lever, precautions being taken to minimise the effect of temperature-variations. Observations are taken while the magnetising current is continuously and cyclically varied. The changes of length are plotted in terms of (1) the external field, (2) the intensity of magnetisation, (3) the square of the intensity. In the case of nickel the two latter curves show no hysteresis. For all three metals it appears that with weak magnetisation the change of length is proportional to the square of the intensity. L. R. W.

64. *Magnetism.* **C. Fromme.** (Wied. Ann. 53. pp. 236–263, 1894.)—A current is maintained in a coil of wire containing an iron or steel core, and either (1) continuously decreased to zero, (2) suddenly interrupted by a contact-breaker, or (3) abruptly diminished by employing the contact-breaker shunted by a resistance R and then brought to zero by continuously increasing this resistance. The amount by which the residual magnetism in the last two cases falls short of that in the first is observed. This decrease is found to be in general less in (3), and the more so the smaller R is, if R consists of liquid resistances or of coils wound on Chaperon's plan, or of the sum of small resistances taken from a Siemens rheostat; but it is anomalously large and inconstant if R consists of large resistances from the rheostat or of the coils of a Wiedemann galvanometer, unless the magnetising current is very small. With given coils the anomaly is greatest when the self-induction is a maximum, and is diminished by promoting eddy currents in the core, or by breaking the contact more slowly. The author refers these effects to electrostatic capacity and self-induction in the coils forming R. L. R. W.

65. *On the Mechanical Action of Waves on Stationary Resonators.—*I. *Electromagnetic Waves.* **P. Lebedew.** (Wied. Ann. 52. pp. 621–640, 1894.)—When a train of waves falls on a stationary resonator which does not react appreciably on the source of the waves, mechanical forces are set up in the resonator. The object of this investigation is to determine, for electromagnetic waves, how the magnitude and sign of such mechanical forces depend on the resonance: both electric and magnetic waves are considered. The waves were produced by the discharge of a U-shaped air-condenser, the coatings of which were connected to the secondary circuit of an induction-coil. Near this was placed a "vibrator," which responded to the waves of the air-condenser, and thus furnished a fairly pure wave of constant period. For magnetic waves the vibrator was a long strip of zinc plate bent double, the two halves being parallel to each other, but by a second bend brought closer together at the ends than the centre; its wave-length was about 320 to 380 cm. The electric vibrator consisted of two parallel plates joined by a copper strip, the wave-length

being 350 cm. The waves emitted by these vibrators were allowed to fall on small resonators consisting of a coil of thin silver wire with its ends attached to two small condenser-plates, the whole being suspended by a torsion-fibre of quartz. For electric waves the plane of the coil was horizontal; for magnetic waves vertical. The resonator was tuned by shortening its coil or altering the distance apart of the end-plates. Indicators were used to ensure that the rate of radiation from the vibrators remained the same throughout the experiments. The experiment consisted in setting the vibrator in action, and after a certain interval reading simultaneously the deflections of the indicator and resonator. It was found that if the wave-length of the resonator was greater than that of the vibrator, repulsion occurred, the angle between the lines of force of the two tended to increase; on the other hand, the resonator was attracted if its waves were shorter than those of the vibrator. The forces of attraction and repulsion were greatest in the neighbourhood of exact resonance, and the behaviour of electric and magnetic waves was the same. The wave-lengths were determined before each experiment by a modification of Lecher's method. The author shows that his results are in accordance with theory, if it be assumed that the vibrations set up in the resonators obey the ordinary laws of elastic vibrations, and if the laws of Coulomb and Ampère hold good for electric vibrations. Regarded from the standpoint of the electromagnetic theory of light, the investigation is an attempt to determine experimentally, by means of large model molecules, the molecular forces called into play by mutual radiation. J. L. H.

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66. *Specific Resistances and Temperature-Coefficients of Copper-Zinc Alloys.* **R. Haas.** (Wied. Ann. 52. pp. 673–690, 1894.)—Haas fused the electrolytic, very pure copper in a Hessian crucible (in a Rössler furnace) under boraa, and added the zinc in pieces of 0·5 gr.: the reaction was very violent, almost explosive. The ingots of the 28 alloys prepared, with from 0 to 100 per cent. of zinc, were drawn through 80 steel eyes, until the diameter was reduced from 4 mm. to less than 1 mm., the wire being frequently heated and rubbed with emery during this process. To eliminate mechanical influences as far as possible, all wires were treated alike. Alloys with from 47 to 99 per cent. of Zn were too hard and brittle to be drawn out, and could therefore not be tested. The analyses were made electrolytically, after Classen's method; traces of iron were present. Resistance and temperature-coefficients were determined between 0° and 100°, at intervals of 10°, increasing and decreasing, two sets of readings being always taken. The two curves show very careful work. The specific resistance rises from pure Cu 0·01576, almost cubically, to a maximum of 0·063 for an alloy with 34 per cent. of Zn, and sinks again, the resistance of the 47 per cent. mixture being the same as that of the 14 per cent. mixture. As pure zinc has a resistance of 0·05683, there must be two more characteristic points in the missing part

of the curve. The temperature-coefficient Cu 0·00432 sank rapidly down to the 5 per cent. mixture (this fall is 70 per cent. of the whole), then more slowly; between 17 and 34 per cent. the curve was almost horizontal, then turned up sharply, the coefficient being the same for 47 per cent. zinc as for 2 per cent. There seems to exist, therefore, an alloy with 34 per cent. of zinc corresponding to the formula $Cu_2Zn$. Laurie's $CuZn_2$ could not have been discovered by this method. H. B.

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67. *Dielectric Polarisation of Liquids.* **B. W. Stankewitsch.** (Wied. Ann. 52. pp. 700–727, 1894.)—The experiments here described have reference to the capacity constants (S.I.C.) of certain fluid dielectrics. The liquids chosen were those having known properties with regard to polarised light: the results indicate that a qualitative relation subsists between S.I.C. and the optical values obtained by Steinheil for the rotation-angle of the plane of polarisation for the B line. A double condenser was used for the electrical tests; it is formed of three copper plates, with distance-pieces of thin glass strips. The liquids are retained in the two narrow interspaces between the copper plates by capillarity. It is pointed out that as the quantity of liquid required to fill the interspaces is very small, the "double-condenser" capacity test is well suited for rare oils. Alternating pressures are employed; those of the condenser-plates being measured by an electrometer. Special attention has been given to the rate of alternation, and the duration of charge $\left(\frac{\tau}{2}\right)$. It is shown that as $\frac{\tau}{2}$ diminishes, the S.I.C. of the substance falls. This diminution is very marked in some of the samples: with oil of lavender, for instance, as $\frac{\tau}{2}$ is given the successive values $\frac{1}{13}$, $\frac{1}{450}$, $\frac{1}{3600}$ secs., the corresponding S.I.C.'s are represented by 20·5, 6·6, and 3·89 respectively. The author tried to work with the higher rates of alternation from Leyden-jar discharges, but the results were unsatisfactory: the S.I.C.'s determined under these conditions were found to agree rather with the period of the induction-coil which charged the jars than with the oscillation-rate of the discharge from the jars themselves. R. A.

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68. *Magnetised Iron Cylinders.* **O. Grotrian.** (Wied. Ann. 52. pp. 735–748, 1894.)—Exception has been taken by du Bois and by Ascoli to the conclusions arrived at by the author in a former paper, and some further experiments are therefore made. Solid cylinders of iron about 3 or 4 diameters long, while magnetised longitudinally by a current, have their magnetisation explored—over one end by measuring the force necessary to detach a small magnet from different points, and at the middle by using two cylinders placed end to end, and having between them an exploring-coil connected to a ballistic galvanometer. It is

found that in each case the magnetisation increases from the axis outwards. The field near the cylinders, and near hollow ones, is also explored with iron filings, and the author deduces magnetic screening on the part of the outer layers of the cylinders. L. R. W.

69. *Moravian Magnetite.* **A. Abt.** (Wied. Ann. 52. pp. 749–757, 1894.)—Bar-shaped specimens of magnetite and pieces of glass-hard steel of the same dimensions are magnetised to saturation and their residual magnetisations compared. The results are calculated in terms of "specific magnetism," *i. e.* magnetic moment per unit mass; and it is found that for specimens about 8 cm. long the specific magnetism of magnetite is the greater, but that this quantity increases rapidly with the length of the body in the case of steel and only slowly in that of magnetite, so that for specimens 14 cm. long the reverse holds. The author also finds that the force which will demagnetise magnetite is smaller than that required by steel. L. R. W.

70. *Measurements in Electric Radiation.* **L. Zehnder.** (Wied. Ann. 53. pp. 162–177, 1894.)—While repeating Hertz's experiments on the passage of electric waves through a prism, using apparatus of about half the linear dimensions of that used by Hertz, and detecting the radiation by its effect upon a vacuum-tube (trigger-tube), the author found it necessary to place screens round the edges of the prism. Without such screens the radiation passed round the edges, and no definite refracted ray could be detected. It was found, however, that the deviation of the ray was dependent on the position of the screens; by moving them in a direction parallel to the base of the prism, differences in the value of the minimum deviation amounting to 25 per cent. of the whole deviation were produced. To avoid the use of screens, observations were made by directing the beam from a parabolic mirror normally on the first face of the prism; the angle of refraction at the second face was then observed. By suitably placing the mirror stray radiation could be cut off. A series of consistent readings gave 1·935 as the mean index of refraction for the prism used, the material of which was a specially dense commercial asphalt (Travers asphalt, density 2·0 to 2·2). Returning to the original arrangement for minimum deviation experiments, the prism was removed, and a position of the screens was found in which they did not produce any deviation of the radiation from its direction on leaving the parabolic mirror; the prism was then replaced, and values varying between 1·926 and 1·940 were found for the refractive index. The behaviour of the screens in the above experiments indicated the existence of diffraction phenomena, so a grating was constructed with three strips of zinc, each 2 metres long and 33 cm. wide, their centres being 80 cm. apart. The radiation fell normally on this grating, and the resulting deviation was measured; the wave-length was found to be 69·4 cm., and agreed with that obtained by other methods. The grating was

then improved by reducing the number of strips to two, each being subdivided into twelve strips of such a size as to respond to the incident vibrations. Measurements of the wave-length of the vibrator by various methods showed that the radiation contained vibrations of several periods; and on examining the radiation which traversed the grating, the deviation was found to depend on the size of the conductor used as detector. The wave-lengths ranged from 66 to 74 cm., the deviations from 56° to 68°, thus giving an "electric spectrum." A new method of detecting nodes and loops in stationary vibrations is described in an appendix to the paper. The stationary waves were set up between the two parabolic mirrors containing the vibrator and resonator respectively, the latter being a vacuum-tube. Between these mirrors the grating-strip of 12 pieces described above was moved about, and it was observed that at every half wave-length, when the strip passed the nodes of the stationary waves, the resonator was unaffected, while at intermediate points its luminosity was reduced, and with the strip at the middle of each loop the tube was completely dark. J. L. H.

71. *Attempts to reduce the Length of Electric Waves in Lecher Wires.* **Wilhelm Donle.** (Wied. Ann. 53. pp. 178-198, 1894.) —Lecher's method of demonstrating the existence of nodes and loops in wires traversed by waves consists in sending the waves along two parallel wires, the ends of which are joined to the electrodes of a vacuum-tube; a bridge which connects the two wires is then moved about until the vacuum-tube ceases to be luminous; the bridge then joins the centres of two ventral segments. The objection to this method is that the waves are usually too long to admit of more than one node and loop in each wire, and the present paper describes methods of reducing the length of the waves so that two bridges can be used simultaneously. The shortest waves detected were of 140 cm. length. The detector was an ordinary glow-lamp with a broken filament; its two terminals, which should not be too close together, were joined to the ends of parallel copper wires 260 cm. or 460 cm. long, according to the waves under experiment. The wires were stretched along a wooden optical bank, and the bridge was carried by one of the stands used with the bank. The waves were obtained from a Blondlot vibrator, consisting of two parallel plates, each provided with a stout wire bent twice at right angles; the two wires terminated in aluminium knobs, and formed a spark-gap. Round these two wires was coiled a carefully insulated wire, the ends of which were joined to the plates of a second similar but smaller vibrator. The coil of wire surrounding the discharge-circuit of the latter vibrator was connected to the Lecher wires. Sometimes, however, they were joined to a third vibrator, and this to the Lecher wires. The waves set up in the Lecher wires were found to be independent of the size of all vibrators except that immediately connected to them, but they were not pure tones. When

more than two bridges were used at the same time, the nodes were not equidistant; the distance between them increased as they approached the ends of the wires furthest from the vibrator. Ebert and Wiedemann, working with similar wires but using a condenser in place of the glow-lamp, found a similar effect, but in their case the nodal distance decreased as the condenser was approached. In each case the wave-length seems to increase as the waves recede from the capacity in the circuit. Lecher regards the rectangle formed by two bridges and the parts of the two wires contained between them as a resonant circuit, while the author regards the bridges as connecting nodes of stationary waves, analogous to those of Melde's experiment in Sound. According to Lecher's theory, the positions of the bridges should be altered by bringing the two wires closer together, the rectangle remaining of constant circumference; while on the author's assumption the nodes should not be disturbed. The results seem to indicate an approach to constancy in the nodal points, but the glow-lamp is not a sufficiently delicate detector to permit of a conclusion being drawn on this subject. J. L. H.

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72. *Dyes in badly conducting Electrolytes.* **O. Lehmann.** (Wied. Ann. 52. pp. 455–461, 1894.)—The author finds that when a current is passed through water or other badly conducting liquid which has been coloured with an aniline dye, regions in which the colour is changed are formed round both electrodes and travel outward from thence. It is shown that their propagation is not due to motion of the fluid, though its velocity is decreased as the viscosity is increased by the addition of gelatine, sugar, or glycerine. When these regions meet, other colour-effects are produced near the area of junction, and the liquid there becomes agitated and heated. The author attributes these phenomena to the diffusion of the products of decomposition from the electrodes through the liquid. He further finds that if a current is passed through a layer of coloured gelatine on a glass slide, elevations of the surface are produced round the electrodes and travel with the regions of colour-change, giving rise to other changes of level when they meet. It is also shown that if the liquid contains small particles suspended in it, changes in their state of aggregation are produced which can also be used to study the progressive change round the electrodes. L. R. W.

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73. *Villari Point in Nickel.* **A. Heydweiller.** (Wied. Ann. 52. pp. 462–472, 1894.)—The author establishes the important fact that, in the case of a nickel wire, if the intensity of magnetisation is small, *i. e.* 5 C.G.S. or less, the magnetic susceptibility at first increases and then diminishes with pulling stress. He also shows the existence of considerable hysteresis when cyclic pulls and pushes are applied to the wire. L. R. W.

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74. *High-frequency Experiments.* **F. Himstedt.** (Wied. Ann. 52. pp. 473–485, 1894.)—An account of some experiments made with apparatus similar to that used by Tesla for attaining high-frequency discharges. A Pt wire (0·05–0·1 mm. diam.), connected between the terminals, at first begins to glow, it then develops a gentle swinging motion as a whole; finally, it sets itself into a zigzag line with sharp bends 0·5 to 1 mm. in length, which remain after the interruption of the current. If the wire, to start with, is given a sag, the bends take up all the slack, so that the axis of the zigzags becomes a right line, about which the bends radiate in all possible planes to one another. A series of tests was made to determine the most suitable material for the points of a spark-micrometer: the author decides upon zinc. If one pole of the high-frequency transformer is connected to earth, and a wire about 2 m. long is stretched straight out from the other pole and then bent back in the middle, so that the second half lies parallel to the first, at a distance of about 5 cm. from it, the discharge is visible at all the outer points of the **U**, but the inner surface of the bend remains dark. A card submitted to the discharge is pierced in many (50–100) places, and not simply in a single point. It is shown that the sign of the electric discharge about the pole of a Tesla apparatus depends upon the gas forming the surrounding medium; thus, by taking two metallic points from the same pole, and discharging one in ordinary air and the other, at the same time, in hydrogen, an electroscope detects positive charges in the air and negative charges in the hydrogen. R. A.

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75. *Hagenbach-Zehnder Experiments.* **Kr. Birkeland.** (Wied. Ann. 52. pp. 486–495, 1894.)—A discussion of some previous papers of Zehnder and others relating to the use of a spark-gap apparatus for detecting electric oscillations. A wire is bent into a rectangular frame, and a spark-gap is formed at the middle of one of the sides. A cut is made in the side of the frame opposite the spark-gap, and into this cut is inserted a simple mica condenser, the terminals of which are connected with a telephone. In a second arrangement the telephone takes the place of the galvanometer in a Wheatstone's-bridge system, and the condenser (which is still in the frame) forms the battery-arm. The author discusses the conditions which determine whether there is to be a sound in the telephone when the frame is influenced by electric oscillations. If the distance between the spark-balls exceeds sparking distance, for a given field, it is shown that the total quantity of "free electricity," at any instant, considered with respect to both halves of the frame, is always zero; and the telephone in such a case is silent. When, however, the spark-gap is reduced, and a spark is allowed to jump across it, the balance of opposite charges no longer holds, and the telephone, consequently, responds. On the other hand, for the more vigorous discharge-rushes, the condenser affords an easier path than the telephone, and takes the principal portion. Equilibrium, therefore,

begins to be restored by way of the mica sheet of the condenser, and it is only the remnant, left beyond this weakening, which affects the telephone. R. A.

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76. *Demonstration of Hertz' Experiments.* **P. Drude.** (Wied. Ann. 52. pp. 499–508, 1894.)—The author describes several arrangements by which electric oscillations in a resonator can be detected without the necessity of darkening the room. These are based on the fact that a spark between two electrodes breaks down the insulating medium between them, and affords a passage for any discharge between the electrodes (compare the Warburg-Zehnder trigger-tube *). An electroscope charged by a dry pile has its leaves and case connected respectively to the two electrodes of a vacuum-tube, which is inserted as the spark-gap in a rectilinear electric resonator. When the resonator responds to vibrations falling on it, the vacuum-tube becomes luminous and the electroscope is discharged; its leaves therefore collapse, diverging again as soon as the vibrations cease. The vacuum-tube used was a trigger-tube, the connections being made to the two auxiliary electrodes. In order that the resonance might not be affected by the electroscope connections, the latter were made near the nodes of the resonator, that is about midway between its electrodes and its ends. For shorter waves the two electrodes were directly connected by a wire, from the centre of which the electroscope connection was made; the other electroscope connection was made to a third electrode in the tube. By projecting an image of the electroscope-leaves on a lantern-screen, most of the Hertz experiments can be shown without darkening the room. Among those described are the formation of stationary waves in front of a plane metallic mirror, experiments with parabolic mirrors, the action of a grating of wires and of screens, the phenomena of multiple resonance, the distribution of electric and magnetic force round a rectilinear oscillation, and the existence of resonance in closed circuits. J. L. H.

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77. *Influence of Pressure on the Specific Inductive Capacity of Water and Ethyl Alcohol.* **W. C. Röntgen.** (Wied. Ann. 52. pp. 593–603.)—This work was undertaken for the purpose of testing Lorentz' formula,

$$\frac{K-1}{K+2}\frac{1}{d} = \text{const.}$$

It was found that the capacity of a condenser consisting of two concentric tubes filled with water or alcohol was not decidedly influenced by subjecting it to a pressure of 300 or 500 atmospheres in a Cailletet compression-pump. A slight increase of capacity was observed in the case of water, but it did not attain 1 per cent. and could not be accurately measured. The above

* L. Zehnder, Wied. Ann. 47. p. 77, 1892.

formula is therefore not valid for wider ranges of pressure. The capacities were measured by the alternate-current method, and it was incidentally found that the capacities appeared to increase with the period of alternation. The resistance of the water diminished as time went on or as the pressure was increased, whereas that of the alcohol increased. The sp. ind. capacities of water and ethyl alcohol were found to be about 86 and 30·5 respectively. E. E. F.

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78. *Supposed Anomaly of the Conductivity of Aqueous Solutions at 4°.* **C. Déguisne.** (Wied. Ann. 52. pp. 604–606, 1894.)—Dr. Silvio Lussana's statement that the temperature-coefficient of dilute saline solutions shows a maximum at 4° C. was shown to be erroneous, by measurements made with solutions of potassium, strontium, and barium nitrates, which were supposed to show the most pronounced maximum. The observed conductivities agreed with the formula $k = k_4[1+\alpha(t-4)]$. The author attributes Dr. Lussana's results to an unequal distribution of temperature in the liquid. E. E. F.

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79. *Conductivity of Ethyl and Methyl Alcohol Solutions.* **B. Völlmer.** (Wied. Ann. 52. pp. 328–356, 1894.)—The ethyl alcohol used for these measurements had a specific gravity corresponding to 100 per cent. in Mendelejeff's tables. Its conductivity, compared with mercury at 18°, varied from $0{\cdot}3\times10^{-10}$ to $0{\cdot}062\times10^{-10}$ that of a sample distilled from lime with which it had been standing for three months. The methyl alcohol had a mean conductivity of $1{\cdot}2\times10^{-10}$ with a lower limit of $0{\cdot}88\times10^{-10}$. The salts dissolved in ethyl alcohol were LiCl, KI, NaI, sodium and potassium acetates, NaCl, $AgNO_3$, $CaCl_2$, and $Ca(NO_3)_2$; in methyl alcohol, potassium and sodium acetates, KI, NaI, and LiCl. In the case of ethyl alcohol, the temperature-coefficient of conductivity increases with increase in dilution. The relation between the temperature-coefficients for conductivity and viscosity is shown in the following table, where $\Delta$ is the former and $\Delta_\eta$ is the latter coefficient:—

| | $\Delta_\lambda$. | $\Delta_\eta$. |
|---|---|---|
| Ethyl Alcohol ..... | 1·84 per cent. | 1·78 per cent. |
| Water ..... | 2·28 ,, | 2·16 ,, |
| Methyl Alcohol .... | 1·8 ,, | 1·45 ,, |

A table is given of the molecular conductivities of these salts, and the ionisation in dilute solutions is calculated, but does not agree with Ostwald's law deduced from aqueous solutions. The limiting values of the molecular conductivity for methyl and ethyl alcohol solutions may be found by multiplying that for aqueous solutions by ·73 and ·34 respectively. S. S.

[Compare with these numbers those found by Whetham (Phil. Mag. Oct. 1894) on the supposition that the ionisation depends

directly on the specific inductive capacity of the solvent and inversely on its viscosity.

| | Water. | Methyl Alcohol. | Ethyl Alcohol. | |
|---|---|---|---|---|
| Whetham .. .. | 100 | 63 | 26 | by theory. |
| „ .... | 100 | 70 | 23 | by experiment. |
| Völlmer .... | 100 | 73 | 34 | „ |

S. S.]

80. *Studies of Gas-Batteries.* **F. J. Smale.** (Zschr. phys. Chem. 14. pp. 577–621, 1894.)—The object of the investigation was to find whether Nernst's theory of liquid-batteries applies to gas-batteries, as supposed by Prof. Ostwald. It was found that the E.M.F. of the gas-battery is independent of the size and quality of the electrodes, provided they are not attacked. The E.M.F. is also independent of the nature and the concentration of the electrolyte, since an approximately constant value of 1·075 volt resulted from the employment of acids, bases, and salts as electrolytes. Lower values, such as those obtained by an H-HCl-O cell, appear to be due to secondary actions. When hydrogen was used at both electrodes, over the same electrolytes with different concentrations, the pole surrounded by the more concentrated solution was always positive. The temperature-coefficient of the H-O battery was 0·001411. The further development of Nernst's formula for increasing temperature may be formulated as follows:—the solution pressure (Nernst's *Lösungstension*) varies inversely as the absolute temperature. E. E. F.

81. *Dielectric Constants.* **W. Nernst.** (Zschr. phys. Chem. 14. pp. 622–663, 1894.)—The author assumes that the electrical behaviour of isotropic substances, at given temperature, is determined by two constants, both of which are of the nature of "conductivity." The first is "conductivity" in the general sense; the second is the measure of the facility with which a given substance transmits electrostatic influences. He denotes these constants by the terms "galvanic conductivity" and "dielectric conductivity" respectively; for clearness, we refer to them as "conductivity" and "S.I.C." It is shown that in the bridge method of comparing capacities, where two condensers, formed of different dielectrics, are balanced against two resistances—using alternating current and telephone—compensation should be provided for the difference of conductivity of the two condensers. A method is described in which non-inductive resistances are added to the condenser bridge-arms for this purpose; it is applied to the measurement of the S.I.C. of some partially conducting fluid dielectrics as well as to the more perfect insulators. It has further been used to determine the variation in S.I.C. of substances in different states of purity, and, consequently, in different conditions of conductivity. Tests follow upon Water, Aniline, Benzol, Amyl alcohol, &c. The apparatus is described at some

length; it includes various condenser devices for liquid dielectrics; there is also given an account of an electrostatic telephone for use in special cases. R. A.

82. *Influence of Pressure on Electrolytic Conductivity.* **I. Fanjung.** (Zschr. phys. Chem. 14. pp. 673–700, 1894.)—When an electrolyte is compressed there will be more ions between two electrodes at invariable distance. A correction is made for this, and for dilute solutions the compressibility is taken as the same as that of water. Twenty different electrolytes are used. The effect of an increase of pressure is found to cause an increase in conductivity very much larger in the case of free organic acids, than in the case of HCl, NaCl, and the sodium salts of the organic acids. The increase in conductivity for the latter group is of the same order as the increase in the viscosity of water with pressure observed by Cohen. The value of the conductivity at infinite dilution, $\mu_\infty$, at any pressure, $p$, is found to be expressed by the equation

$$\mu_{p\infty} = \mu_{1\infty}(1 + ap).$$

With all the organic acids a pressure-increase produces an increase in ionisation. Accepting the general principle that substances tend to pass into a state in which they occupy less volume when they are submitted to pressure, it appears that in the ionised state the organic acids occupy less volume. This volume-diminution is calculated for the organic acids, and is found to be not very different for all the organic acids examined. S. S.

83. *Potentials of Hydrogen and of some Metals.* **B. Neumann.** (Zschr. phys. Chem. 14. pp. 193–230, 1894.)—Hydrogen absorbed by spongy platinum precipitates Au, Ag, Hg, Pd, Cu, As, Sb, Bi from their solutions (not the other metals) because the hydrogen is alloyed and can pass into the ionic state. In various normal acids, hydrogen does not acquire the same potential, because they are dissociated to a different degree. The absolute potentials of H are: in sulphuric acid (60 p. c. of dissociated molecules), −0·238; hydrochloric acid (90 p. c.), −0·149; phosphoric acid (8 p. c.), −0·205; acetic acid (1 p. c.),−0·15. It is immaterial whether the H is absorbed by platinum or by palladium. In the third part of the paper Neumann determines the absolute potentials of twenty metals (as such or amalgamated) in solutions of their own salts. The values, except those for Al, agree with Wright and Thomson's. That the anion has no influence upon the potential, provided the state of dissociation be maintained, is proved by experiments with 24 thallium salts; a monovalent metal was chosen for the sake of simplicity. The last part gives the absolute potentials of over forty reducing and oxidising agents. H. B.

84. *Electric Convection, Sedimentation, and Diffusion.* **O. Lehmann.** (Zschr. phys. Chem. 14. pp. 301–316, 1894.)—When

electrodes immersed in liquids are highly charged with alternating currents, regular convection-currents are set up. With continuous currents, diselectrification of the particles is more difficult; clear spaces form round the electrodes, in which vortex motions can be noticed. Lehmann examines these phenomena under the microscope by admixing oils, varnishes, soluble and insoluble colouring-matters to water. Friction against the glass, and the conductivity of the particles complicate the phenomena, and give rise to secondary poles. Prussian-blue in acetal gives very pretty streaks like little fish which face the positive pole and rapidly turn round on reversing the current. Unless the pressure is driven too high, the particles will generally aggregate near one pole. Holtz has been trying to utilise this electric sedimentation. If electrolytic action is possible, as in the case of liquid chinese-ink, which contains glue and certain salts, the phenomena become more complicated. Dark or light spaces form round the electrodes with well-defined edges, which, overlapping, produce colourless zones with dark fringes, some parts being in violent agitation. Lehmann experimented with very many dyes, congo-red, eosin, malachite-green, &c., in water, alcohol, glycerin (which proved very suitable), and gelatine. The end is mostly formation of a precipitate somewhere between the electrodes. There seems to be chemical decomposition at the electrodes, and an abnormally rapid electric diffusion of the decomposed particles. Induction-machines were used. H. B.

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85. *Conductivity of Solutions of Calcium, Strontium, and Barium Salts.* **A. C. MacGregory.** (Wied. Ann. 51. pp. 126–139, 1894.)—The author has determined by Kohlrausch's method the conductivity of aqueous solutions of the sulphate, chloride, nitrate, and acetate of calcium, the chloride, nitrate, and acetate of strontium, barium chloride, silver acetate, and potassium oxalate. The concentration of the solutions in gram-equivalents per litre varied, in general, between 0·0001 and 3. The temperature of observation was, as a rule, 18°. Expressed as a function of the concentration, the molecular conductivity gives regular curves which are almost rectilinear, unless in the case of the most dilute solutions of silver acetate. The author finds that for conductivity observations the optical telephone of Wiens and the ordinary telephone serve equally well. He also finds that very pure water ($K = 1{\cdot}3 \times 10^{-10}$) may be obtained by the use of condensers of good glass, provided sufficient time be allowed for the condenser to be well washed out by the distillate before any is collected for use. J. W. R.

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86. *Polarisation at Precipitated Septa between Electrolytes.* **P. Springmann.** (Wied. Ann. 51. pp. 140–155, 1894.)—Two electrolytic solutions which, in contact, form a precipitate are separated by a porous partition of parchment, clay, or gypsum, a current is passed from one solution to the other, and the electromotive force of polarisation is measured. The paper is concerned

with the influence exerted on the polarisation by the current-density, the concentration of the solutions, the temperature, and the nature of the porous partition and precipitate. J. W. R.

87. *Standard Cells.* **K. Kahle.** (Wied. Ann. 51. pp. 174–203, 1894.)—The preparation and constancy of the Rayleigh H pattern of cell is first examined. Results are stated in terms of ·00001 volt. The E.M.F. of an H cell prepared with well-purified chemicals will not differ ·0001 volt from the normal value, and in experiments on 29 cells extending over $1\frac{1}{2}$ years no greater variation than ·0001 volt from the mean has been observed. The influence of impurities is studied by adding Mg, Na, As, Pb, Cd, Fe to the zinc amalgam, and $MgSO_4$, $FeSO_4$, ZnO to the zinc sulphate; amalgamated zinc is also tried; and it is concluded that with the H form of cell disturbing influences which would cause greater variations than ·0001 volt can without great difficulty be avoided.—Feussner's pattern of cell. The E.M.F. of this pattern is as constant as that of the H form, but the mean value of the cells examined was about ·0003 volt higher than the mean for the H cells.—Four cells were prepared according to the Board of Trade memorandum, and it is concluded that they do not satisfy the requirements of a standard.—The temperature-coefficient for the H pattern for the range of temperature between 10° and 30° is $-0{\cdot}000814-0{\cdot}000007\ (t-15)$. With this coefficient, provided the cells are protected from sudden variation of temperature, it is possible to obtain a value of E.M.F. accurate to ·0001 volt, and, if there are sudden variations, to ·001 volt. The other cells did not work regularly. A determination of the absolute value of the E.M.F. to a greater degree of accuracy than 1·438 volt at 15° should now be made, since the H cells have so great constancy. S. S.

88. *Standard Cells.* **K. Kahle.** (Wied. Ann. 51. pp. 204–211, 1894.)—The following points may be noticed as being slightly different from the mode of procedure recommended by the Board of Trade. The containing vessel is a modified H, and the two platinum electrodes are sealed through the glass. The zinc amalgam consists of 9 parts by weight mercury and 1 part by weight zinc. The zinc sulphate is tested with congo-red for acid, and with potassium sulphocyanide for iron. If there is no reaction in each case, the salt may at once be used. If acid be present, equal weights of the crystals and water are digested with zinc filings until all evolution of gas ceases, and the solution on cooling gives a precipitate of $Zn(OH)_2$, coloured brown with iron oxide. To remove the last traces of iron, the solution is to be electrolysed with a current of ·2 ampere and electrodes 50 square cm. in area, at 60° to 80° C. for six hours. It should then be acid and iron free. If not, it is to be re-treated. The solution, free from iron and acid, has 50 grams of purified mercurous sulphate added to every litre to react with the basic zinc sulphate. Crystals from this solution are ready for use. If the mercurous sulphate is slightly yellow, it

indicates the presence of basic salt which must be converted by dilute sulphuric acid to the normal salt. The acid is then to be removed until the first traces of a yellow colour appear, indicating the complete removal of the excess of acid. S. S.

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89. *Kathode Rays.* **P. Lenard.** (Wied. Ann. 51. pp. 225–267, 1894.)—Kathode rays, which Hertz had proved to be capable of transmission through thin metallic plates, may be obtained and studied outside the vacuum-tube in which they are produced by letting them impinge upon a "window" made of a small piece of aluminium 0·00265 mm. thick, which is inserted in the wall of the tube facing the kathode. The rays produce a faint diffused glow in the air just outside the window, and make phosphorescent bodies shine brightly. They produce no sensation on the retina direct. They are deflected off the window by a magnet and intercepted by thin quartz, but not by thin glass or collodion. Air is a turbid medium for kathode rays when at atmospheric pressure. The rays are propagated and diffused in it in the same manner as a beam of light in milk. They are photographically active, about as much so near the window as the sun on a misty day. In high vacua, on the other hand, the propagation tends to become rectilinear. When a tube exhausted to $0{\cdot}01 \times 10^{-6}$ atmospheres adjoined the window, the rays were propagated in straight lines to a distance of 1·5 m. The author concludes that the kathode rays are processes in the ether, and, like light, independent of the presence of matter for their propagation. Other gases behaved in the same manner as air. The amount of diffusion and of illumination by the passage of the rays is strictly proportional to the density of the gas. The turbidity also depends upon the pressure at which the kathode rays are generated. At lower pressures in the generating tube the rays were sharper outside, and *vice versâ*. For kathode rays, gases which are practically homogeneous as far as light is concerned are made heterogeneous by their molecular structure. E. E. F.

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90. *Polarisation and Electrolysis.* **O. Wiedeburg.** (Wied. Ann. 51. pp. 302–345, 1894.)—In this paper the author seeks to represent analytically what is known regarding polarisation, and to evaluate the quantities which shall accurately measure the polarisation. The assumptions upon which his discussion is based are:—(1) The active electromotive force drives the ions to the electrodes; there they become the seat of new electromotive forces, which, acting in opposition to the original electromotive force, regulate the current according to Ohm's law. (2) All the ions which reach the electrodes are not instrumental in producing back-electromotive force; some are neutralized and lose their ionic character. (3) The number of ions which can accumulate at an electrode is limited. At any instant the number accumulating is proportional to the difference between the number already present

and the limiting number. Some of the consequences of the theory are in accord with known facts, but the author is still engaged upon the experiments which were specially designed to test its validity. J. W. R.

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91. *Feeler Electrodes for finding Resistance of Electrolytes.* **F. Kohlrausch.** (Wied. Ann. 51. pp. 346–350, 1894.)—The conductivity of a liquid is usually determined in a resistance-cell to which the electrodes are permanently attached. The author here describes three forms of electrodes which can be dipped into the liquid contained in any suitable vessel. The electrodes are small and are made of platinized platinum fitted to capillary tubes which serve to make the connections. The forms are designed respectively for very feeble, feeble, and good conductors.

J. W. R.

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92. *Measurement of Coefficients of Induction.* **M. H. Abraham.** (J. de Phys. 3. pp. 145–159, 1894.)—*Coefficient of Mutual Induction.* One of the coils, whose coefficient of mutual induction is required, is connected in series with a resistance and a make-and-break (K) to the terminals of a battery of low internal resistance, preferably an accumulator. This inducing circuit has a resistance R (of order 1000 ohms). The other coil is put in series with a standard resistance $r$ (of the order 1 ohm), a make-and-break (K′), one coil of a differential galvanometer G of about 5 ohms, and a resistance; the resistance of this induced circuit is $R'+r$, and is of the order 100. Connected also to the terminals of the battery is a resistance C (about 1000) in series with a resistance B (10), and to the terminals of B is connected a resistance A (order 1000 but adjustable) in series with the other coil G (5) of the differential galvanometer. This latter circuit is called the compensator-circuit. The contacts K and K′ are made by a rotating commutator driven by a motor whose speed is noted by a stroboscopic method; they are made and broken thus: K′ closed, K closed, K′ opened, K opened. The resistance A is adjusted until there is no deflection in the galvanometer, when the commutator closes, and breaks the circuit $n$ times per second. The commutator is then stopped so that both circuits are closed, a break made in the inducing circuit, the ends of which are connected to the terminals of $r$, and A adjusted to A′ to again give a balance. Then as an approximate formula (accurate to 1 in 10,000)

$$M = \frac{1}{n} \cdot r \cdot \frac{R}{R+r} \cdot \frac{A'+G+B}{A+G+B}.$$

The stroboscopic method of obtaining the speed consists in attaching to the end face of the axle of the motor a disc divided into concentric circles having respectively 1, 3, 4 . . . 8 black sections on a white ground. This disc is lighted intermittently by reflecting on to it through a lens the light of a glow-lamp by means of a

mirror attached to an electrically driven tuning-fork, and arranging the speed of the motor so that one of the circles appears immoveable.

*Coefficient of Self-Induction.* A Wheatstone's bridge is employed, the branches P, Q, and S are inductionless, and L the coil whose coefficient is to be measured is inserted in R; the battery is connected through a resistance of about 1000 and the make-and-break K; and one coil of the galvanometer through the make-and-break K', both in the usual manner; the compensator-circuit is the same as before. The bridge is carefully balanced for constant current, the commutator started, and A adjusted to give a balance. The commutator is then stopped, and a standard resistance $r$ (of the order 1) inserted in R, the compensator-circuit being adjusted to give a balance by altering A to A'. Then to within one part in 1000,

$$L=\frac{1}{n}\cdot r\cdot\frac{2P+G}{2P+G+r}\cdot\frac{A'+B+G}{A+B+G},$$

when P=Q= between 50 and 200 ohms. In both the above methods the author claims that an accuracy of one part in 1000 can be fairly easily obtained, the only quantities necessary to be accurately known being the speed $n$ (which should not be greater than 12), and the standard resistance $r$, for which he usually employs a standard ohm; the other resistances only come in as corrections, and need not be so accurately known. E. C. R.

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93. *Thermoelectric Cells of Metals and Salt Solutions.* **A. Hagenbach.** (Wied. Ann. 53. pp. 447–480, 1894.)—Two metal plates were immersed in a salt solution, and the liquid round one electrode gradually heated, while the temperature of that round the other was kept constant. Tables and diagrams are given showing the total electromotive force produced at each temperature, with different strengths of solution. When the metal of the electrodes was the same as that of the salt in solution, it was found that the differences in thermoelectromotive force produced by alterations in concentration were different for different salts, but that for similar acids the maxima fell at equivalent positions. The electromotive force increased faster than the difference in temperature, especially with dilute solutions. No maximum at 5 p. cent. was found, as Ebeling thought, but the electromotive force increased still further with increasing dilution and seemed to tend to a limiting value, as Nernst's theory requires. When, on the other hand, platinum electrodes were used, the thermoelectromotive forces remained very similar for various sulphates and chlorides, both in magnitude and in variation with concentration. The differences in electromotive force produced by variations in concentration were in general greater than with unpolarisable electrodes. The change in thermoelectromotive force with rising temperature seemed to depend only on the temperature itself, and not on the difference in temperature. The green modification of chrome-alum gave a higher electromotive force than the violet. W. C. D. W.

94. *Locus of Charge of a Condenser.* **A. Kleiner.** (Wied. Ann. 52. pp. 728–734, 1894.)—An attempt is here made to localise the various electric charges of a condenser; to determine what proportion of the total charge is held by the dielectric, and what proportion belongs to the conducting coatings. Separable condensers, made by coating thin mica sheets on one side with tin-foil, and floating them, foil side upwards, upon a mercury surface, were used for this research. After charging, the mica plates were lifted from the mercury; the tin-foil discs were then removed from the mica by insulating pincers, and connected to earth. The condenser was now built-up again, and discharged through a galvanometer. Immediately afterwards, the condenser was charged and discharged in the usual way, through the galvanometer. The difference of the two galvanometer-readings is assumed to be a measure of the part of the total charge held by the tin-foil. Owing to the numerous difficulties which attend such tests, the results are given, in their present stage, with some hesitancy. R. A.

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95. *Movement of Dielectric Body in Homogeneous Electric Field.* **L. Graetz** and **L. Fomm.** (Wied. Ann. 53. pp. 85–94, 1894.)—It is here stated that, according to the generally accepted theory of dielectrics, a very small, homogeneous, isotropic, dielectric sphere, or ellipsoid, should neither rotate nor move progressively, when freely suspended within a uniform electrostatic field. The conflicting fact that thin rods and thin discs (particular cases of ellipsoids) do rotate in such a field, leads the authors to consider some modifications of Maxwell's hypothesis. Experiments are made upon discs of various dielectrics, in fields presumed to be uniform; the discs are suspended from bifilars between two condenser-plates. The results indicate that if V is the potential-difference between the plates of the condenser, and $\alpha$ the angle of rotation of the dielectric disc which V produces, then $V=C\sqrt{\alpha}$, where C is a reduction-factor. Having established this relation for a particular apparatus, it was used afterwards as a "dielectric voltmeter." When alternating pressures of high frequency were to be measured, a difficulty appeared in attaining a uniform field between the condenser-plates; for although, by having the conducting plates large as compared to the dielectric disc, the field was considered uniform as regards *space*, yet, owing to the rapidity of change of potential through the dielectric, there was likely to be heterogeneity of field in point of *time*,—due to phase-progression. The experiments seem to show, however, that the rotation was the same whether the alternations were of high or low frequency; the effect is therefore not regarded as of much importance. R. A.

## CHEMICAL PHYSICS.

96. *Change of Free Energy on mixing Concentrated Solutions.* **W. Nernst.** (Wied. Ann. 53. pp. 57–68, 1894.)—The author finds that in general the greatest amount of work which can be obtained by mixing two solutions of different strengths in the same solvent is equivalent to the heat evolved by the process, or that the alteration in free energy coincides with the alteration in total energy. The maximum amount of work can be calculated by following some reversible process by which mixing can be effected, such as electrolytic transfer, isothermal distillation, &c. Two calomel cells made up with zinc-chloride solutions of different concentrations, joined in series *against* each other, give a balance of electromotive force which is nearly independent of the temperature, so that $E-Q=T\frac{dE}{dT}=0$ and $E=Q$. From Regnault's numbers for the vapour-pressures, the work done in transporting one gram-molecule of water from one solution of sulphuric acid to another of different strength can be deduced. The heat-evolution corresponds with the change in free energy, except in the case of very strong solutions, the data for the vapour-pressures of which are very doubtful. The variations from the normal case of proportionality to the number of molecules in solution, which are shown by the depression of the freezing-point and vapour-pressure, stand in close connection with the heat of dilution. With substances possessing positive heat of dilution, the lowering of vapour-pressure increases faster, and with substances having negative heats of dilution slower, than in proportion to the number of dissolved molecules. All natural processes are subject to the relation

$$F-Q=T\frac{dF}{dT},$$

where F= decrease of free energy and Q the decrease of total energy. In the case of concentrated solutions the above considerations show that F=Q. W. C. D. W.

97. *Diffusion in Alcohol.* **W. Kawalki.** (Wied. Ann. 52. pp. 300–327, 1894.)—Tables are given for the diffusion-constant of certain salts in alcoholic and in aqueous solution. The salts examined are NaI, LiCl, potassium and sodium acetates, $Ca(NO_3)_2$, KI, $AgNO_3$. The temperatures at which the measurements are made being slightly different, the author is able to calculate the temperature-coefficient and confirms the result of de Heen that this is independent of the nature of the salt. He finds a mean coefficient of ·024, and de Heen found for aqueous solutions alone the result ·026. A table is given showing the ratio of the diffusion-constant for aqueous and alcoholic solutions, and the average result is about 3. This is compared with the ratio of the conductivity for infinite dilute in aqueous and alcoholic solutions, and

this number is found to be approximately 3. The results with stronger solutions are more concordant than with dilute, convection-currents interfering in the latter case. The actual value of the diffusion-constant is greater when the initial concentration is smaller. The results for NaI, potassium acetate, KI, and sodium acetate agree very well with Nernst's formula deduced from the theory of ionisation. S. S.

98. *Influence of Pressure on the Properties of Solutions.* **G. Tammann.** (Zschr. phys. Chem. 14. pp. 433–445, 1894.)—The internal pressure of a solution can be represented by $\Omega = K + \Delta K + p$, where K is the internal pressure of the solvent, and $p$ the external pressure. The change of internal pressure can be connected with the alteration in physical properties, and hence, by observation of the influence of external pressure on the properties of a solution, the difference between the internal pressures of the solvent and solution can be deduced. Experiments on the influence of external pressure on electric conductivity have been made by Finks, and from his results for sodium-chloride, hydrochloric-acid, and zinc-sulphate solutions the values of $\Delta K$ are calculated. The change in conductivity may be due to a change in the number of free ions, or in the frictional resistance of the liquid to their motion, probably the latter. W. C. D. W.

99. *Study of Gas Reactions by Volume Alteration.* **M. von Recklinghausen.** (Zschr. phys. Chem. 14. pp. 491–505, 1894.)—The vessel containing the reacting gases was connected by means of a long narrow tube full of air with a self-registering manometer. The air in the tube served to isolate the gases, and hence contact with any liquid was avoided. Observations were made on mixtures of hydrogen and chlorine, and of carbon monoxide and chlorine in diffused light. As soon as the light was allowed to fall on the mixed gases there was a rapid increase of the volume for a few seconds, followed by a diminution that got gradually slower till the reaction was complete. In the case of hydrogen and chlorine, the author found that if the light was removed after acting for a few seconds, the volume sank at once to very nearly the original volume of the mixture. If the gas was then re-illuminated, the volume rose again, but not so high as it was just before the light was removed, from which the author concludes that when the formation of HCl is once started the reaction continues for a time even in the dark. Ethylene and chlorine, which combine without the action of light, showed no increase of volume at the beginning of the reaction. The gases used were not specially pure and contained one or two per cent. of air. J. W. C.

100. *Application of Kohlrausch's Method to Measurement of the Conductivity of Slightly Dissociated Substances.* **M. Wildermann.** (Zschr. phys. Chem. 14. pp. 231–246, 1894.)—The conductivity of

solutions of dichloracetic, trichloracetic, and $\beta$ resorcylic acids in absolute alcohol was determined by Kohlrausch's method. Ostwald's formula for the effect of dilution on conductivity as deduced from the dissociation theory, expresses the results of the measurements in the case of trichloracetic acid. . The dissociation of acetic acid and its chloro-derivatives increases as the number of chlorine atoms gets greater in alcohol as it does in water. Resorcylic acid does not fall in the same place as in aqueous solutions. The author considers Kohlrausch's method inconvenient for slightly dissociated substances like these. W. C. D. W.

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101. *Measurement of the Electric Conductivity of Slightly Dissociated Compounds.* **M. Wildermann.** (Zschr. phys. Chem. 14. pp. 247–271, 1894.)—In cases where Kohlrausch's method is inconvenient good results can be obtained by using higher E.M.F.'s (140–150 volts), and thus making the polarisation practically negligible. A galvanometer is used instead of a telephone. The conductivity is deduced from observations on the current, the external resistance being always very large. The solutions were contained in long thin tubes of various dimensions. The results for aqueous solutions of oxalic and acetic acids agreed with those given by Kohlrausch's method, and observations were then made on alcoholic solutions of dichloracetic and trichloracetic acids. The latter obeys the dilution law up to a temperature of 25° C. W. C. D. W.

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102. *Rate of Reaction and Boiling-Point.* **J. E. Trevor** and **F. L. Kortright.** (Zschr. phys. Chem. 14. pp. 149–150, 1894.)—The authors investigate the rate of reaction in the case of the hydrolysis of cane-sugar in presence of dilute acid. They remark that many physical properties which vary with the number of molecules in unit volume may be used. They commend the boiling-point determination because of its convenience. The writers use a Beckmann's boiling-point apparatus, and employ succinic acid for conversion. In the known expression for reactions involving one molecule, the original rise in boiling-point and the successive further increments replace respectively the quantities under the log sign. Thirteen observations are given, for which the value of the logarithmic expression, when the substitutions indicated are made, remains very approximately constant within extreme variations of under 4 per cent. A. G.

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103. *Dissociation of Water.* **W. Nernst.** (Zschr. phys. Chem. 14. pp. 155–156, 1894.)—Correcting Ostwald's value for the dissociation for the difference in potential between the acid and base used, the author gets $0{\cdot}8 \times 10^{-7}$. W. C. D. W.

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104. *Sedimentation and Absorption of Pigments.* **O. Lehmann.** (Zschr. phys. Chem. 14. pp. 157–160, 1894.)—The phenomena of precipitation of pigments held in suspension by the addition of salts and other substances are strikingly exhibited by Wolff's liquid

indian-ink. This is unaffected by substances like pyrocatechine, resorcine, or aniline dyes, but is at once precipitated by grains of sal ammoniac and citric acid, or pigments like malachite-green and Hofmann's violet. Butyl and amyl alcohol have the same effect. Sedimentation may be restrained by adding gelatine, thus increasing the viscosity of the medium. Precipitation appears to be usually due to the deposition of the substance added upon the particles in suspension. E. E. F.

105. *Corresponding Solutions.* **G. Tammann.** (Zschr. phys. Chem. 14. pp. 163–173, 1894.)—The thermal expansion of a solvent is in general different from that of solutions of salts in it, but by a pressure $\Delta k$ can be brought to the same value. The concentrations of solutions of the chlorides of potassium, sodium, lithium, barium, and ammonium at which the values of $\Delta k$ are the same are determined. These agree well with Kremer's and Bender's corresponding volumes. Such solutions should show no change in volume on mixing. The corresponding solutions of the carbonates and sulphates of sodium and potassium possess the same molecular concentration, and are also isohydric, but this is not always the case. W. C. D. W.

106. *Stochiometry of the Velocities of the Ions.* **G. Bredig.** (Zschr. phys. Chem. 13. pp. 191–288, 1894.)—The author gives a general account of the determination of the migration of the ions, the electrical conductivity of solutions, the amount of dissociation, and the limiting value of the molecular conductivity. The independent ionic velocities can then be calculated by Kohlrausch's theory. A long series of tables is given showing the molecular conductivity of many substances (chiefly organic) in aqueous solution, both from the results of the work of other observers and from new determinations by the author, and the ionic velocities calculated from these data are then tabulated. The following general results are given. The velocity of elementary ions is a periodic function of their atomic weight, similar elements being found at corresponding points in the curve. The velocity of compound ions is a "convergent additive" property, each addition of $CH_2$ to the chemical composition producing a smaller decrease in velocity. As an example the table for the velocities of the anions of the formic acid series may be here given :—

| | Anion. | $a$. | $da$ for $CH_2$. |
|---|---|---|---|
| Formic acid .. | $HCO_2$ | 51·2 | −12·9 |
| Acetic „ .. | $H_3C_2O_2$ | 38·3 | − 4·0 |
| Propionic „ .. | $H_5C_3O_2$ | 34·3 | − 3·5 |
| Butyric „ .. | $H_7C_4O_2$ | 30·8 | − 2·0 |
| Valeric „ .. | $H_9C_5O_2$ | 28·8 | − 1·4 |
| Caproic „ .. | $H_{11}C_6O_2$ | 27·4 | |

The influence of substitution is also considered. W. C. D. W.

107. *Dielectric Constants and Chemical Equilibrium.* **W. Nernst.** (Zschr. phys. Chem. 13. pp. 531–536, 1894.)—The energy of an electrically charged system surrounded by a medium of specific inductive capacity D is equal to $\frac{1}{2D}\Sigma eV$. If we consider the ions as electrically charged bodies it follows that the forces between them are reduced the more, the higher the dielectric constant of the solvent, and there must exist a force of attraction between the ions and the solvent. The order of the dissociation of hydrogen chloride in benzene, ether, isobutylic alcohol, ethyl alcohol, and methyl alcohol is the same as the order of their dielectric constants. A simple method of determining the constants is indicated. [The same effect has been pointed out by Prof. J. J. Thomson (Phil. Mag. 1893) and applied to the question of the relative ionisation powers of solvents by W. C. D. Whetham, who finds a quantitative agreement for solutions of calcium chloride in water, methyl and ethyl alcohols, if a correction is made for the relative viscosities (Phil. Mag. Oct. 1894).] W. C. D. W.

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108. *Diffusion of an Electrolyte in Alcohol.* **W. Kawalki.** (Wied. Ann. 52. pp. 166–190, 1894.)—The author has determined the rate of diffusion of certain electrolytes in alcohol with the view of testing the consequences of the hypothesis of electrolytic dissociation. The electric conductivities of the solutions employed have already been determined by Völlmer. In this, the first instalment of his paper, the author discusses the various experimental methods, and adopts an apparatus which is practically identical with that used by Scheffer. Special precautions had to be taken on account of the hygroscopic nature of alcohol, and from the fact that the salts were but sparingly soluble in it. A modification of Stefan's process was employed in correcting the observed values of the diffusion coefficient. J. W. R.

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109. *Solutions.* **P. Duhem.** (J. de Phys. 3. pp. 44–69, 1894.)—A general proof is given of the following theorem:—Every formula obtained by applying thermodynamical principles to a mixture or a solution, every other law being excluded, remains valid no matter what assumptions be made regarding the state of the substances which compose this mixture or solution. It follows, therefore, that by means of thermodynamical considerations alone no clue can be obtained as to whether dissolution has been accompanied by any change, chemical or otherwise, in the condition of the dissolved substance. J. W. R.

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110. *Rotativity of Solutions.* **A. Aignan.** (J. de Phys. 3. pp. 110–119, 1894.)—This paper contains a discussion of the validity of Biot's law $[\omega]=\frac{\omega}{l\epsilon\delta}$, and of Landolt's law $[\omega]=A+Bq+Cq^2$ for the specific rotatory power. Experiments with terebenthene and essence of turpentine dissolved in various solvents

gave the following results:—in certain oils and petroleum $[\omega]$=constant, in alcohol $[\omega]$ increases with dilution, and in carbon disulphide $[\omega]$ decreases with dilution. An indirect verification of the law $[\omega]$=constant is afforded by experiments on sucrate of potassium. A solution of this substance is supposed to contain, in addition to the salt, some of it dissociated into sugar and potash. The rotatory power of the solution will, therefore, be the sum of the rotatory power of the active sucrate of potassium and of the active sugar; and the actual value obtained will be determined by the quantity which is dissociated. On the hypothesis that the amount of dissociation is proportional to the amount of inactive solvent, the deviation of the observed values from a value calculated on the supposition of no dissociation from the rotatory power of each constituent should be proportional to the amount of inactive solvent or to the dilution. This is stated to be the case with sucrate of potassium. Biot's experiments on tartaric acid and Gernez' on malic acid are discussed from the same point of view. S. S.

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111. *Thermal Effects in Electrolysis.* **A. Campetti.** (Nuov. Cim. 34. pp. 64–74, 1894.)—The author describes experiments to determine the whole amount of heat developed in the voltameter during electrolysis and also, separately, that developed at each electrode. The amount of heat evolved at the anode is in every case different from that evolved at the kathode. From the total heat evolved (Q), the current (I), the E.M.F. between the terminals ($e$), and the E.M.F. of polarisation, he calculates the heat due to secondary action by the formula

$$Q_s = Q - \frac{1}{J} It(e-p).$$

For sulphuric acid the secondary heat varies from 20 to 60 per cent. of the Joule heat, but the results are somewhat discordant. Acetic acid gave better results. The secondary heat was zero, and hence the different amounts of heat developed at the two electrodes must be due to a Peltier effect. For HBr and bromides the author finds $Q_s$ zero. For chlorides and iodides it is always positive.

J. W. C.

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112. *Rotativity and Dissociation of Electrolytes.* **G. Carrara.** (Nuov. Cim. 34. pp. 51–54, 1894.)—The paper consists of an investigation of the statement of Nernst that salts containing an optically active ion should have equal rotatory powers when completely dissociated in solutions of equivalent strengths. The author finds that hydrobromide, nitrate, and propionate of nicotine have specific rotatory powers, 12·17, 12·58, and 12·18 respectively in very dilute solutions. Schwebel had previously found for the hydrochloride, sulphate, and acetate 14·44, 14·52, and 13·81, which the author considers as equal to the results of

his own experiments within the limits of experimental error. Unpublished experiments by Zecchini on salts of conine give similar results. Hence the author concludes that, in spite of some difficulties which he discusses, the rotatory power of optically active acids and bases in solution probably depends on the electrolytic dissociation. J. W. C.

113. *Conductivity and Viscosity of Electrolytes.* **V. Monti.** (Nuov. Cim. 34. pp. 75–80, 1894.)—The author determines the viscosity-coefficients of mixtures of glycerine and water, and compares them with the electrical conductivities of some salts of the alkalies in similar mixtures, but is unable to find any general relation connecting them. He uses his observations to test Mützel's formula (Wied. Ann. 43.) for the viscosity of salt solutions, and finds they do not support it. J. W. C.

114. *Thermoelectricity of Electrolytes in the Solid State: Influence of a Molecular Transformation.* **S. Lussana.** (Nuov. Cim. 34. pp. 99–125, 1894.)—Sticks of solid electrolytes were prepared by fusing the salts in glass tubes. A stick of one salt was placed between two of the other salt, one of its ends being joined to its neighbour by pushing the glass tubes through holes in the side of a little cork vessel filled with mercury. The other end was joined to its neighbour inside another glass tube, which could be filled with mercury, and which passed through a beaker filled with oil. This formed the hot junction, its temperature being varied from 50° to 200°. It was found that the electrolytes tested also obeyed Volta's law in the solid state. $KClO_3$, $ZnCl_2$, $HgCl_2$, $NaClO_3$, and $(NH_4)NO_3$ were coupled with $KNO_3$ and then with $NaNO_3$. The E.M.F.'s varied in the two cases by amounts corresponding to the E.M.F. between $KNO_3$ and $NaNO_3$. They all present the phenomenon of inversion. An anomaly appears in the curves where the salt undergoes a molecular transformation. If two portions of the same salt are taken, the electricity flows from the form stable at the higher temperature to that of the lower temperature across their junction. The E.M.F. thus developed between hexagonal and rhombic $KNO_3$ is 0·055 volt. E. E. F.

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